ACRES CONSULTING SERVICES LIMITED
5259 Dorchester Road
P.O. Box 1001
Niagara Falls, Ontario
L2E 6W1

Occupational Health Survey

WORKER EXPOSURE TO EPOXY RESINS AND ASSOCIATED SUBSTANCES

December 1984

Prepared for

Occupational Health and Safety Division
Standards and Programs Branch
Ontario Ministry of Labour

DISCLAIMER

This report was commissioned by the Occupational Health and Safety Division of the Ministry of Labour. The findings reported and the views expressed are those of the authors and do not necessarily reflect the views of the Ministry of Labour or of its staff. This report is being made available for the benefit of those wishing to extend their knowledge of occupational health and safety matters.

TABLE OF CONTENTS

GLOSSARY
LIST OF TABLES
LIST OF FIGURES

EXECUTIVE SUMMARY

Page

1 - INTRODUCTION ---------- 1
1.1 - Terms of Reference and Study Approach ------- 1

2 - PROPERTIES, RESIN TYPES, AND FORMULATION PROCESSES IN ONTARIO ---------- 3
2.1 - Definition of Epoxy Resins ---------- 3
2.2 - Properties ---------- 6
2.3 - Types of Epoxy Resins in Ontario ---------- 7
2.3.1 - Diglycidyl Ether of Bisphenol A (DGEBA) Resins ---------- 7
2.3.2 - Epoxy Novolac Resins ---------- 7
2.3.3 - Cycloaliphatic Epoxy Resins ---------- 8
2.3.4 - Brominated Epoxy Resins ---------- 8
2.3.5 - Flexibilizing Epoxy Resins ---------- 8
2.4 - Ontario Production and Formulation Processes ---------- 9
2.4.1 - Production of DGEBA Solid Epoxy Resins ---- 9
2.4.2 - Formulation of Protective Coatings -------- 9
2.4.3 - Formulation of Adhesives ---------- 13
2.5 - End Usage Formulations ---------- 14
2.5.1 - Automotive Industry ---------- 15
2.5.2 - Construction Industry ---------- 16
2.5.3 - Reinforced Plastics Industry ---------- 19
2.5.4 - Electrical/Communications Industries ------ 21

3 - CURING AGENTS, DILUENTS AND FILLERS ---------- 23
3.1 - Curing Agents ---------- 23
3.1.1 - Aliphatic Amines ---------- 23
3.1.2 - Aromatic Amines ---------- 24
3.1.3 - Anhydride Hardeners ---------- 24
3.1.4 - Catalytic Curing Agents ---------- 25
3.1.5 - Polyamides (Flexibilizers) ---------- 26
3.1.6 - Polysulfides (Flexibilizers) ---------- 26
3.1.7 - Amino and Phenol-Formaldehyde Resins as Curing Agents ---------- 27
3.2 - Diluents/Solvents ---------- 27
3.2.1 - Reactive Diluents ---------- 28
3.2.2 - Nonreactive Diluents (Solvents) ---------- 28
3.3 - Fillers and Pigments ---------- 28

	Page
4 - CURRENT AND PROJECTED USAGE PATTERNS FOR EPOXY RESINS IN ONTARIO	31
4.1 - Current Usage Patterns	31
4.2 - Future Trends	35
5 - WORKER EXPOSURES AND CONCENTRATIONS IN THE WORK ENVIRONMENT	39
5.1 - Epichlorohydrin (ECH)	39
5.2 - Formulation Processes	41
5.2.1 - Production of Solid Epoxy Resins (Flakes)	41
5.2.2 - Coatings Manufacture	43
5.2.3 - Adhesives Manufacture	44
5.3 - End Usage Applications	45
5.3.1 - Powder Coatings	45
5.3.2 - Solution Coatings	46
5.3.3 - Construction Industry	46
5.3.4 - Reinforced Plastics Industry	47
5.3.5 - Electrical/Communications Industries	48
5.4 - Ontario Workers at Risk by Industry Sector and Occupational Category	49
6 - HEALTH EFFECTS	51
6.1 - Epichlorohydrin	53
6.2 - Bisphenol A	54
6.3 - Uncured Epoxy Resins	54
6.3.1 - DGEBA Resins	54
6.3.2 - Brominated Epoxy Resins	55
6.3.3 - Epoxy Novolac Resins	56
6.3.4 - Cycloaliphatic Epoxy Resins	56
6.4 - Cured Epoxy Resins	56
6.5 - Curing Agents	57
6.5.1 - Polyamines	58
6.5.2 - Anhydrides	58
6.5.3 - Polyamides	59
6.6 - Diluents	59
6.6.1 - Glycidyl Ethers	59
6.6.2 - Solvents	60
6.7 - Fillers and Pigments	60
6.8 - Ontario Workers at Risk by Industry Sector and Occupational Category	60
7 - MONITORING METHODS FOR EPOXY RESIN CHEMICALS AND DUSTS	63
7.1 - Air Monitoring Techniques	63
7.1.1 - Ontario Air Monitoring Practices	63
7.1.2 - NIOSH Air Monitoring Techniques	64
7.2 - Medical Monitoring	67
8 - EXPOSURE CONTROLS	71
8.1 - Engineering Controls	71
8.1.1 - Containment	71

	Page
8.1.2 - Ventilation and Dust Collectors	73
8.1.3 - New Technology	75
8.2 - Protective Equipment	75
8.3 - Administrative Controls	78
8.4 - Use of Substitutes	81
8.4.1 - Substitution of a Different Resin	81
8.4.2 - Substitution of a Higher Molecular Weight Resin for One of Lower Molecular Weight	82
8.4.3 - Substitution of a Different Curing Agent, Catalyst or Diluent	82
8.5 - Economic Impact of Controls	82
8.6 - Worker Attitude to Controls	84
8.7 - Employer Attitude to Controls	84
8.8 - Trade Association Concerns	87
9 - EXPOSURE LIMITS	89
9.1 - Canada	89
9.2 - United States	90
9.3 - Other Countries	90
10 - RECOMMENDATIONS FOR ACTION OR FURTHER STUDY	91

APPENDIX I - ORGANIZATIONS CONTACTED DURING EPOXY RESIN STUDY

APPENDIX II - CHEMICAL AND PHYSICAL PROPERTIES OF SPECIFIC COMPOUNDS ASSOCIATED WITH EPOXY RESINS IN ONTARIO

APPENDIX III - TYPICAL CURING AGENTS AND DILUENTS FOR EPOXY RESINS

APPENDIX IV - COMMERCIAL EPOXY RESIN FORMULATIONS (Courtesy Dow, Ciba-Geigy & Shell)

APPENDIX V - HEALTH EFFECTS OF EPOXY RESINS AND ASSOCIATED SUBSTANCES

APPENDIX VI - NIOSH AIR MONITORING AND ANALYTICAL PROCEDURES FOR SOME SUBSTANCES ASSOCIATED WITH EPOXY RESINS (NIOSH, 1977 - 1980)

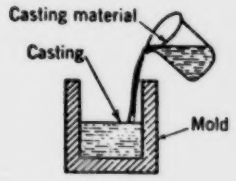
APPENDIX VII - SAMPLE MATERIAL SAFETY DATA SHEETS

APPENDIX VIII - EXPOSURE LIMITS FOR COMMON SUBSTANCES ASSOCIATED WITH EPOXY RESINS

APPENDIX IX - EPOXY RESIN QUESTIONNAIRE

LIST OF REFERENCES

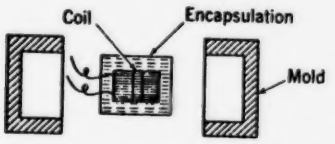
GLOSSARY

accelerator	A substance which hastens a reaction, usually by acting in conjunction with a catalyst or curing agent
ACGIH	American Conference of Governmental Industrial Hygienists
adduct	Crystalline mixtures (not true compounds) in which molecules of one of the components are contained within the crystal lattice framework of the other component. The complexes are stable at room temperatures but the entrapped component can escape when the mixture is melted or dissolved.
casting/casting resin	 (Lee and Neville, 1967)
CNS	Central nervous system
conjunctiva	The mucous membrane that lines the inner surface of the eyelids and is continued over the forepart of the eyeball
curing agent	A hardener or cross-linking agent which is reacted with the epoxy resin to form the thermoset resin (term sometimes includes catalysts used to accelerate the curing process)
dermatitis	Inflammation of the skin
diglycidyl ether of bisphenol A (DGEBA)	The most widely used epoxy resin resulting from the reaction of epichlorohydrin with bisphenol A in the presence of sodium hydroxide
diluent	A substance used with epoxy resins primarily to reduce viscosity

edema

An abnormal excess accumulation of serous fluid in connective tissue or in a serous cavity

encapsulation (electrical)



(Lee and Neville, 1967)

epoxy resin

Any molecule containing one or more epoxide groups capable of being converted to a useful thermoset form

epoxy resin system

A system composed of two or more reactive components, i.e., the resin + curing agent, and often a reactive diluent and modifier for changing the physical characteristics of the final product

ester

An often fragrant compound formed by the reaction between an acid and an alcohol, usually with elimination of water

exotherm

In a polymerization reaction the heat, if liberated during a short course of time, will result in a substantial increase in temperature of the reactive mixture. This temperature increase (measured by thermocouple) is referred to as exotherm.

filament winding

Continuous glass strand or tape is wet with catalyzed resin and wound continuously on a form

filler

A relatively inert substance added to a plastic compound to reduce its cost and/or to improve physical properties, particularly hardness and impact strength

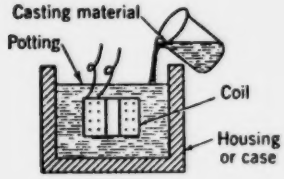
fluidized bed

To suspend particles of a loose bed of materials in a rapidly moving stream of gas or vapour to enhance a chemical or physical reaction

grout

A thin mortar used for filling spaces (as the joints in masonry)

hepatotoxin	Capable of causing injury to the liver
hyperplasia	An increase in size of a tissue or organ resulting from proliferation of cells or the development of additional tissue of which the organ is composed but excluding tumor formation
hemoptysis	Release of blood from the respiratory tract
hemolytic anemia	Excessive destruction of red blood cells
intraperitoneal	Existing within or going into the membrane that lines the cavity of the abdomen
lacrimation	Secretion of tears, especially when abnormal or excessive
laminate	To roll or compress into a thin plate
leukocytes	White blood cells
leukopenia	A condition in which the number of leukocytes circulating in the blood is abnormally low
mutagen	A substance that tends to cause a change in individual genes or a structural alteration in chromosomes
necrosis	Localized death of tissue or bone
nephrosis	A non-inflammatory degeneration of the kidneys chiefly affecting the renal tubules
neuritis	An inflammatory or degenerative lesion of a nerve marked by pain, sensory disturbances and impaired or lost reflexes
NIOSH	National Institute for Occupational Safety and Health
novolac	Produced by the reaction of formaldehyde with a small excess of phenol using an acid catalyst

OSHA	Occupational Safety and Health Administration (US Department of Labour)
paresthesia	A sensation of prickling, tingling or creeping on the skin that has no objective cause
pot life	Time available for use of an epoxy system after the resin and curing agent are mixed
potting (electrical)	 (Lee and Neville, 1967)
STEL	Short-term exposure limit, i.e., the maximum concentration allowed where workers can be exposed to a substance for a certain period, usually 15 minutes. ACGIH recommends that the STEL should not be repeated more than 4 times per day and that there should be at least 60 minutes between successive exposures at the STEL
subcutaneous	Under the skin
teratogen	A substance causing developmental malformations
TLV	Threshold limit value
TWA	Time-weighted average concentration of a substance in the workplace, usually measured on the basis of an 8-h workday or over a 40-h workweek
TWAEC	Time-weighted average exposure concentration which allows nearly all workers to be exposed for a 40-h week without adverse effects (Ontario Ministry of Labour)

LIST OF TABLES

Number	Title
4.1	Ontario Epoxy Resin Usage Patterns (1981)
4.2	Ontario Epoxy Resin Usage by Type (1981)
4.3	Estimated 1982 Ontario Usage of Curing Agents in Epoxy Resins
4.4	Typical Uses for Epoxy Resins in Ontario
5.1	Concentrations of Epoxy Resin and Bisphenol A Dusts in the Ontario Workplace
5.2	Occupational Exposures to Epichlorohydrin During Use of Epoxy Resins (Berger et al., 1980)
5.3	Workers with Potential Exposure to Epoxy Resins, Bisphenol A and/or Associated Curing Agents and Diluents in Ontario
6.1	Ontario Workers' Compensation Board Allowed Claims Relating to Contact Dermatitis From Resins and Fume Inhalation from Plastic Processes
7.1	Patch Test Concentrations for Epoxy Resins and Selected Curing Agents/Diluents (Adams, 1983)
7.2	Summary of Responses Obtained During Ontario Industry Survey of Medical Monitoring Practices
8.1	Engineering Controls in Place for Epoxy Resins in 1983 Based on Ontario Survey Results
8.2	Protective Equipment Available for Workers in the Ontario Epoxy Resin Industry in 1983 (Based on Survey Results)
8.3	Administrative Controls in Place for Epoxy Resins in 1983 Based on Ontario Survey Results
8.4	Summary of Labour Organization Comments Regarding Worker Exposure to Epoxy Resins
8.5	Summary of Trade Association Comments Regarding Worker Exposure to Epoxy Resins

LIST OF FIGURES

Number	Title
2.1	Flow of Epoxy Resin Imports into Ontario
2.2	Chemical Structures of Epoxy Resins in Ontario

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

Production, Consumption and Future Projections

Basic liquid epoxy resins are not produced in Ontario. However, many different resin types (primarily in liquid form) are imported into Ontario, i.e., the diglycidyl ether of bisphenol A (DGEBA), epoxy novolacs, cycloaliphatics, and brominated and flexibilizing epoxies. Dow Chemical in Sarnia is the only Ontario producer of solid epoxy resins (flake form) which are manufactured by modifying liquid DGEBA resins. These modified epoxy resins are sold to formulators for further modification. Formulators, in turn, sell to the end users.

It is estimated that approximately 3,400 tonnes of epoxy resins are used in Ontario annually and that there will be an annual increase in usage of approximately 5 percent over each of the next 5 years.

Epoxy Resin Applications in Ontario

Epoxy resins are primarily used by the coatings industry with lesser quantities used in adhesives, reinforced plastics, electrical, communications, and construction applications.

Other Substances Reviewed

In addition to epoxy resins, other substances reviewed were the basic ingredients of DGEBA resins (epichlorohydrin and bisphenol A), curing agents, catalysts, diluents and fillers used by Ontario formulators and end users.

Health Effects of Epoxy Resins

Contact dermatitis is the primary acute effect resulting from accidental skin contact with liquid epoxy resins. Respiratory difficulties (e.g. mild nasal irritation, asthma attacks) and eye irritation may also result from exposure to vapours or dusts from resin curing agents or from exposure to cured epoxy dusts. There is not sufficient monitoring data available to allow "no effect" levels to be determined.

No evidence was found in the literature of carcinogenicity or teratogenicity as a result of occupational exposure to cured or uncured epoxy resins. However, there

Health Effects of Epoxy Resins (cont)

has been considerable controversy in recent years regarding the potential for liquid epoxy resins to produce carcinogenic activity in animal tests. Mixed results were obtained in early tests and there was concern that the epoxy resins used in the tests were not carefully characterized chemically. Also, Shell indicates that many of the earlier resins contained impurities that are not representative of epoxy resins currently produced (Berger et al., 1980). More recent animal tests with liquid DGEBA epoxy resins by Holland et al. (1981) and Shell/Ciba-Geigy (unpublished) indicate no carcinogenic potential, however, this requires further substantiation by independent investigators.

Mutagenicity tests with liquid and solid epoxy resins have produced mixed results which suggest that some epoxy resins may have the potential to cause genetic changes.

A brief discussion of the health effects resulting from exposure to individual components of epoxy resin mixtures is also included in this report.

Ontario Workers at Risk

It is estimated that approximately 800 workers in 30 Ontario plants are involved in the formulation of epoxy resin products. This number does not include end users of the product (e.g., automotive, electrical, communications, reinforced plastics, aerospace and construction applications) who are estimated to number between 1,000 and 10,000. It is difficult to pinpoint the number of end users more accurately due to the large range of industries involved and the intermittent use of epoxy resins in many applications. The small-scale end users (e.g., in autobody shops, construction applications, etc) are probably at greatest risk, since they are less likely to be knowledgeable of the potential hazards and proper controls required to protect workers.

Monitoring Methods

NIOSH air sampling and analytical methods are available for epichlorohydrin, bisphenol A, diglycidyl ether of bisphenol A, aliphatic amines, and for a number of anhydrides and glycidyl ethers.

Monitoring Methods (cont)

The most common medical monitoring technique is the patch test for skin sensitization.

Exposure Controls

Enclosed processes are generally used by most Ontario formulators except where small batches are prepared. However, it was observed that on occasion, large blending containers in the coatings and adhesives industries were left uncovered and this should be remedied to minimize exposure to organic vapours. Protective equipment (especially impervious gloves and coveralls) are important to avoid skin irritation through accidental handling of epoxy resins. Overalls, gloves (cotton and synthetic), safety glasses, face shields, dust masks, organic vapour respirators, and eye wash stations are standard equipment available in Ontario plants where epoxy resins are formulated. During plant visits it was observed that dust masks and gloves were not always worn in work areas requiring these special precautions.

Good ventilation and air extractors are necessary to control nuisance dusts and vapours during loading, unloading and packaging operations as well as during application of the resin. Ontario plants surveyed indicate use of general ventilation and some use of local exhaust systems over blending containers but not in all cases.

Employer/ Employee Reaction to Controls

Ontario workers in the communications industry would probably welcome government controls in view of their union's perceived hazard of working with some epoxy products based primarily on mutagenicity tests. Other Ontario unions contacted did not express similar concerns. Employers generally do not feel that government controls are necessary for epoxy resins unless a specific component of the resin or resin system is shown to be a serious hazard in the occupational environment.

Exposure Limits in Other Jurisdictions

As of January 1984, no occupational exposure limits exist for epoxy resins in any jurisdiction. However, some criteria do exist for individual components of the

resin, i.e., epichlorohydrin, bisphenol A,* some common curing agents, and glycidyl ethers.

Exposure Limits in Other Jurisdictions (cont)

*In British Columbia only

1 - INTRODUCTION

1 - INTRODUCTION

1.1 - Terms of Reference and Study Approach

The Ontario Ministry of Labour awarded a contract to Acres to collect background information on epoxy resins and their ingredients, including curing agents, for the purpose of analyzing the risks of worker exposure to these substances in Ontario.

The objectives of the study were to identify

- current and projected use of epoxy resin systems in Ontario
- nature, cause and extent of worker exposure to ingredients in epoxy resin systems
- acute and chronic health effects of work place exposure to epoxy resin systems
- number of workers potentially exposed by industry sector and occupational category
- workplace air sampling and analysis techniques
- engineering and administrative controls available
- reaction of employers to various government control strategies
- workers' rationale if they are seeking government controls
- factors to be considered in assessing economic impact of controls
- occupational exposure limits in other jurisdictions.

Epoxy resins are industrial plastics which belong to a class of thermosetting materials which includes phenolic and polyester resins. Thermosetting materials are capable of becoming permanently rigid when heated or cured (i.e., with a hardening agent). This is in contrast with thermoplastic resins such as polyethylene and polyvinyl chloride which are capable of softening or fusing when heated and of hardening again when cooled.

This report includes information on epoxy resins imported into Ontario in the uncured state as well as epoxy resin systems (resin plus curing agent) used in Ontario.

The study involved a literature review, discussions with recognized experts, and a questionnaire survey of the Ontario epoxy resin industry. The Ministry of Labour developed a contact list comprising 38 companies, 7 labour organizations and 6 trade associations. Fourteen companies in key industry sectors were selected for a plant visit and the remaining companies and organizations were surveyed by telephone. These plant visits were for purposes of observing working conditions and obtaining information from management. They were not industrial hygiene visits, and neither air monitoring nor industrial hygiene recommendations were included.

A list of the organizations contacted is contained in Appendix I. Companies were selected with the objective of obtaining a representative sample of all Ontario industry sectors involved in epoxy resin use or distribution. The cooperation of the companies surveyed is gratefully acknowledged, particularly where visits were made to plant and/or office facilities. Special thanks are extended to Dow Chemical and Shell Canada who provided substantial technical assistance.

2 - PROPERTIES, RESIN TYPES, AND FORMULATION PROCESSES IN ONTARIO

2 - PROPERTIES, RESIN TYPES, AND FORMULATION PROCESSES IN ONTARIO

In Ontario the epoxy resin industry is limited to

(a) companies which import resins from other jurisdictions

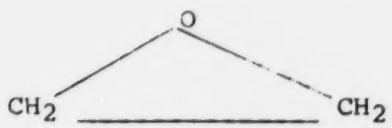
(b) companies which modify and formulate these imported resins into suitable coatings and adhesives products for end users

(c) the end users of the resins (e.g., automotive, aerospace, construction, reinforced plastics, electrical/communications industries).

This report is directed to activities related to epoxy resins that take place in Ontario as shown in Figure 2.1.

2.1 - Definition of Epoxy Resins

Epoxy resins are polymers containing more than one epoxide group (a 3-membered ring containing two carbon atoms and one oxygen atom). The term epoxy is a prefix that indicates the presence of an epoxide group in a molecule or compound. The simplest epoxide is ethylene oxide.



ethylene oxide

Figure 2.2 shows the chemical structures of various types of epoxy resins known to be in use in Ontario. The diglycidyl ether of bisphenol A (DGEBA) resins are, by far, the most commonly used epoxy resins in Ontario (see Section 4).

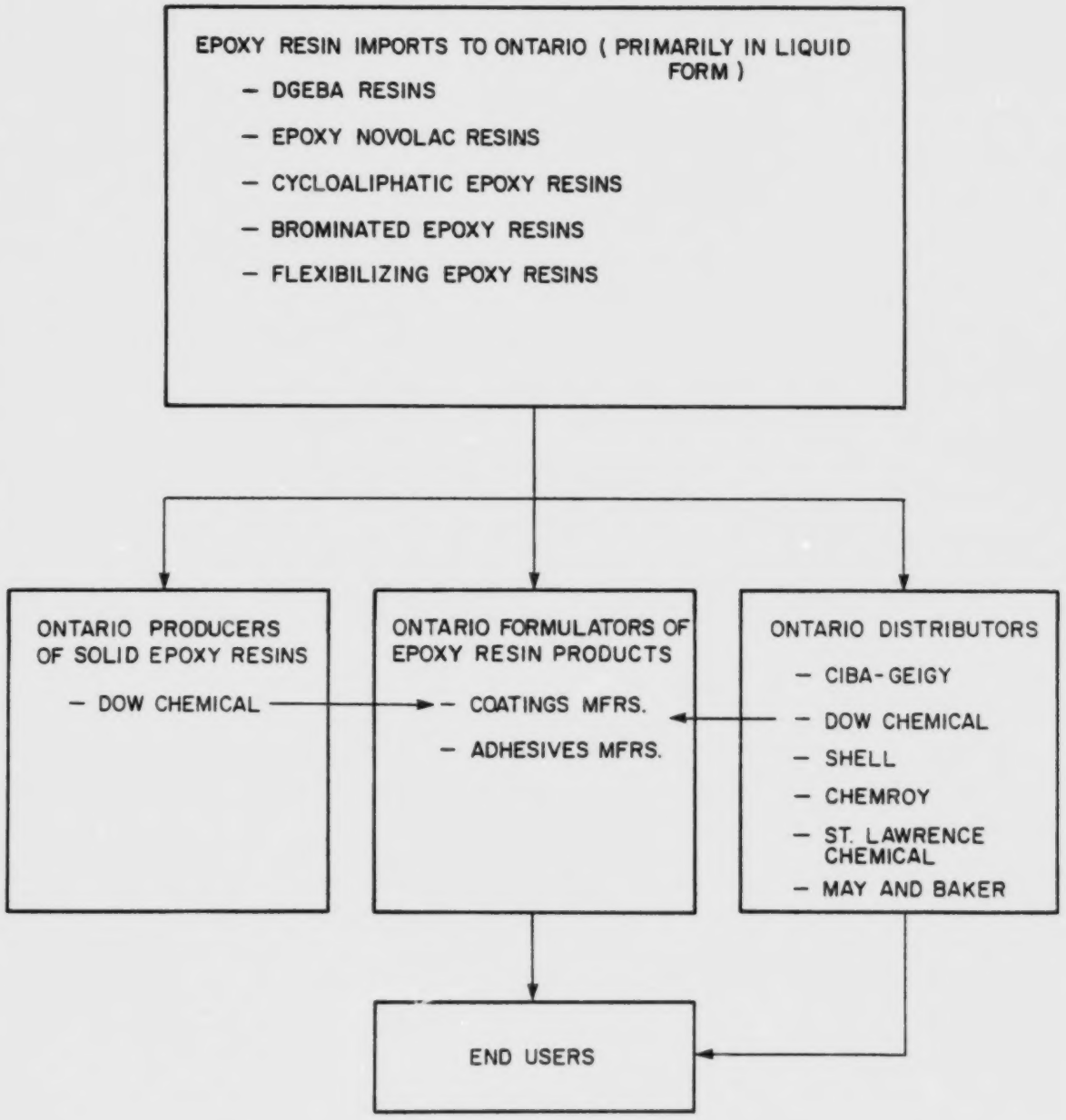
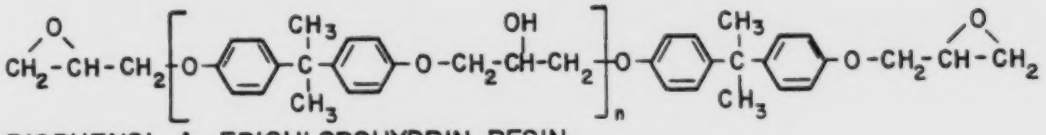
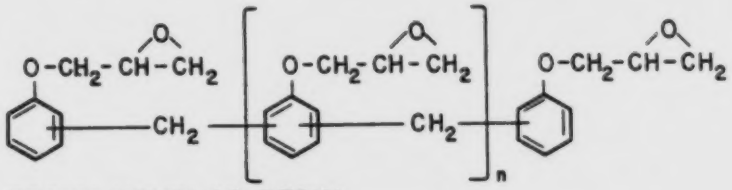


FIG. 2.1

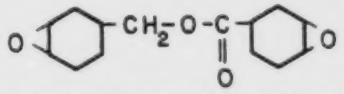
FLOW OF EPOXY RESIN IMPORTS INTO ONTARIO



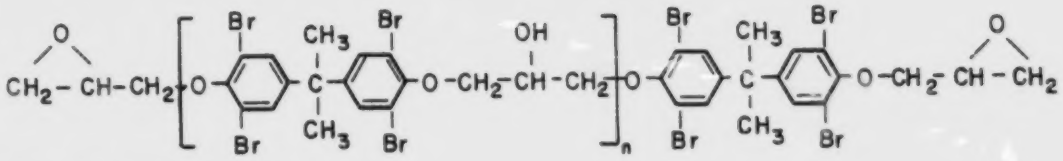
BISPHENOL A-EPICHLOROHYDRIN RESIN



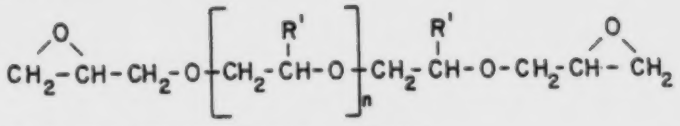
EPOXY NOVOLAC RESIN



BASIC MATERIAL FOR CYCLOALIPHATIC EPOXY RESIN (CARBOXYLATE TYPE)



BROMINATED EPOXY RESIN



FLEXIBILIZING EPOXY RESIN

SOURCE: VELTEN, 1975

FIG. 2.2

CHEMICAL STRUCTURES OF EPOXY RESINS IN ONTARIO

Before epoxy resins can become useful products, they must first be "cured", that is, the reactive epoxy groups must be cross-linked by polymerization into a 3-dimensional matrix.

Uncured epoxy resins have not yet had a curing agent (or cross-linking agent) added. Cured resins are also known as epoxy resin systems, i.e., the material resulting from a reaction of the curing agent with an uncured epoxy resin. Prior to being cured, epoxy resins may be in liquid or solid form.

2.2 - Properties

General physical properties of epoxy resins which make them attractive for a wide range of applications include low shrinkage during cure, excellent adhesive and mechanical strength, good chemical resistance, heat resistance and electrical resistance. Flexibility, impact resistance, viscosity, toughness, heat resistance and curing conditions (pot life and temperature) can be influenced by the choice of curing agent used. Appendix II lists the chemical and physical properties of bisphenol A, epichlorohydrin, and a number of curing agents and diluents used in modifying basic epoxy resins. This list is limited to those chemicals identified in the industry survey as being present in Ontario. Note that epichlorohydrin is included in Appendix II only because most of the epoxy resins used in Ontario are based on DGEBA resins; epichlorohydrin is not used in the Ontario epoxy resin industry and is believed to be present only in trace quantities in the resins imported into Ontario.

A more detailed list of common curing agents and diluents used in the epoxy resin industry is contained in Appendix III. This list is not intended to be comprehensive but is believed to be generally representative of substances currently used.

2.3 - Types of Epoxy Resins in Ontario

Both Dow Chemical and Shell Canada report that liquid epoxy resins are not produced in Ontario. However, Dow and a number of other Ontario companies import a range of epoxy resins as outlined in Figure 2.1.

A brief description of the various types of epoxy resins imported into Ontario is provided below. For an indication of the range of commercial epoxy resins available in North America, see Appendix IV.

2.3.1 - Diglycidyl Ether of Bisphenol A (DGEBA) Resins

DGEBA resins are manufactured by reacting epichlorohydrin and bisphenol A in the presence of aqueous caustic soda. By varying manufacturing conditions and the amount of epichlorohydrin, resins of low, intermediate or high molecular weight are produced (Dowd, 1968). Diglycidyl ether of bisphenol A (DGEBA) is synthesized from this process and is the primary epoxy resin imported to Ontario. It may be imported in liquid or solid form. Generally, low molecular weight resins which are liquid at room temperature have "n" values less than 1; ("n" is the number of repeating units in the resin chain); solid resins have "n" values of 2 or greater (Breitigam, 1983).

2.3.2 - Epoxy Novolac Resins

These resins are prepared outside Ontario by reacting epichlorohydrin with a novolac resin (a reaction product of phenol and formaldehyde) in an acidic medium. The resulting epoxy novolac resins are polyglycidyl ethers of a novolac resin which are imported into Ontario.

"Epoxy novolacs" as they are called, provide an alternative to bisphenol A-based resins when superior elevated temperature performance, chemical resistance, or adhesion are required (Dow, 1978).

2.3.3 - Cycloaliphatic Epoxy Resins

Epoxy resins can also be produced from cycloaliphatics such as cyclopentadiene which have been epoxidized via peracetic acid oxidation (Handlovits, 1983). These imports have significant superiority over DGEBA resins in their resistance to formation of carbon deposits on their surface, and have become particularly important in electrical applications due to their arc-track resistance (ability of a material to withstand continuous arcing in a contaminated moist atmosphere) (Stevens, 1968).

2.3.4 - Brominated Epoxy Resins

These epoxy resin imports contain 15 to 50 percent bromine and are usually produced by reacting tetrabromobisphenol acetone (TBBA) with DGEBA. These flame-retardant resins are usually mixed with other epoxy resins to provide flame retardance to the product (Handlovits, 1983).

2.3.5 - Flexibilizing Epoxy Resins

Flexible epoxy resin imports are desirable for increased elongation and impact resistance. Flexible epoxy resins can be made from polyglycols, polythiols, aliphatic acids and hydroxyl-terminated compounds. When used alone, flexible epoxy resins have low physical strength properties so they are normally used in blends with DGEBA or novolac-based epoxy resins.

Generally they are used in a range of 10 to 30 percent with DGEBA or novolac-based resins when improved

resilience is required without too large a loss in strength properties (Meath, 1968).

2.4 - Ontario Production and Formulation Processes

Following import into Ontario, the liquid epoxy resin may be transformed to solid flakes or may be modified in another manner by adding polyamines, polyamides, diluents, solvents and/or fillers. As might be expected, these processes differ depending on end use.

2.4.1 - Production of DGEBA Solid Epoxy Resins

To modify the imported liquid epoxy resin to solid form (flakes), Dow Chemical pipes the liquid resin (DGEBA) from outside storage tanks to an outside reactor. Bisphenol A is then added to the reactor and an exothermic reaction takes place. The reacted epoxy mixture is then pumped inside after it cools and, while it is still somewhat plastic, it is extruded on a line and fed into a flaker. It is subsequently crushed and bagged for sale as epoxy resin flakes, primarily for the coatings industry.

2.4.2 - Formulation of Protective Coatings

Epoxy resins are used by the Ontario coatings industry in the following ways.

(a) Epoxy Ester Paints

In one Ontario plant visited approximately 5,200 kg of DGEBA solid epoxy resin flakes were used in each batch to manufacture 16,000 L of

esterified epoxy resin paints. This type of coating is commonly used for tank exterior coatings, marine primers and as refinishes in car body shops. The process involves the esterification of the hydroxyl groups of the resin with unsaturated fatty acids. A batch will take approximately 8.5 hours to process and in this plant six batches were made in the first 9 months of 1984.

In the third floor loading area 25-kg bags of epoxy resin flakes are dumped into a reactor by two workers over an 80-min period. There is a cyclone dust collector operating over the epoxy resin loading center and the workers wear gloves. However, they do not find it necessary to wear dust masks since there is no noticeable irritation to the respiratory system. Fatty acids are already in the reactor which is closed and heated to a proprietary preset temperature prior to the solid epoxy resins being added. Solvent is then added directly through pipelines from outside tanks into the reactor. A batch is tested for acid number* and viscosity 30 minutes after it reaches maximum temperature. This is done via a take-off tap which is enclosed in a see-through box. The tap is turned on from outside the box and a small quantity of epoxy ester drops into a small container inside the box; it is subsequently removed for laboratory analysis. When a batch is satisfactory the heat is switched off and the mixture is transferred to an enclosed thinning tank where solvent is again added and the batch is cooled. Filtration then takes place by circulating the batch through a filter press and back into the thinning tank to remove particles.

*Number of milligrams of potassium hydroxide required to neutralize one gram of sample.

In this area two workers wear leather and cotton gloves and spend about 15 minutes cleaning the filter press. A local exhaust system is located above the filter press cleaning area to vent solvent emissions away from the worker. A final step involves pumping the epoxy ester into large storage tanks in the enamel manufacturing building for subsequent use in epoxy ester paints. Alternatively the product may be drummed and the worker wears rubber gloves and has an air extractor (local exhaust) operating over the drums. If workers get the epoxy-based solution on their skin they are encouraged not to use solvents (although some do). It is recommended that they use barrier creams prior to handling the epoxy based solution and cleansing creams or soap and water to remove any solutions from the skin.

(b) Air-Dried Paint Systems

There are two types.

- A one-component epoxy-based paint (with no hardener) e.g., floor paints or for coating the interior of pipelines to reduce friction. The paint air-dries and the film left behind is the dried resin.

- A two-component epoxy-based coating for use in industrial metal coatings. Users are supplied with a resin-based coating and a separate container of polyamine or polyamide curing agent. The curing agent is modified by the formulator by adding a solvent and filler to make the viscosity the same or higher than the resin-based coating.

In the above applications solid DGEBA resins and dry pigment are received by the formulator in

25-kg bags and dumped into ball, pebble or sand mills depending on the type of end product required. Solvent is added from outside tanks via feeder lines. The resin, pigment and solvent are then rotated in closed mills for 12 to 16 hours to make a smooth concentrated liquid. In the operation observed, one worker is employed full time in this area and wears rubber gloves. A dust mask is optional for pigment dusts; some workers use them and some don't. There was general ventilation in this area but no local exhaust ventilation.

The mixture is then drained to an open 1,300-L pot or directly into a larger enclosed tank on a lower floor of the building. At this point more solvent, resin and other additives (to adjust the viscosity) are added to the mixture. Some worker exposure will be experienced when adding resin to the mixture (see Section 5.2.2) but the primary concern would be to solvent emissions.

After mechanical mixing when the containers have been covered, the epoxy-based paint is drained into open 194-L (45-gal) drums or 21.5-L (5-gal) pails and then sealed.

(c) Epoxy Baking Systems

Liquid DGEBA resin is mixed with a melamine-, phenol- or urea-formaldehyde resin hardener and drummed for subsequent use as can coating liners. To effect a cure these epoxy resin-based coatings must be heated.

The processes for formulating this product are similar to those described in (b) above. Based on one Ontario formulator's comments liquid epoxy resin would represent about 2 percent of the final product.

(d) Epoxy Powder Coatings

There are two formulators of epoxy powder coatings in Ontario. This product can be formulated in one of three ways (Lee and Neville, 1967)

- by grinding together dry, high-molecular weight resin with a powdered curing agent

- by melting the dry resin and curing agent and, when cooled, grinding the resultant solid

- by reacting liquid epoxy resin with a curing agent to achieve a solid state and subsequently grinding it.

No details were available on which of the above methods is used in Ontario.

2.4.3 - Formulation of Adhesives

The use of liquid epoxy resins to formulate adhesives also involves a batch process. In one Ontario plant a 170-L [45-gal(US)] drum of liquid DGEBA resin was lifted by a fork-lift vehicle, tilted and poured into an open blending container of approximately 1,200 L (264 gal) sitting on weigh scales. The open blending container was then placed under a mixing machine. Mechanical agitator arms were lowered into the resin container and the machinery was turned on. At this point an elephant trunk air extractor was placed over the container to collect dusts while a worker added filler (e.g., amorphous silica or similar substance) to the resin. In this case the worker added five 4.5-kg (10-lb) bags of filler to the resin over a period of approximately 30 minutes. After each bag of filler has been added, the air extractor is moved away and the container is tightly closed while the resin and filler are mixed for a few minutes. A final step in the

mixing process involved operation of a vacuum pump for approximately 1 hour (when the container was closed) to remove air bubbles from the resin paste. The resin mixture was then transferred via pipes to 170-L [45-gal(US)] drums and sealed for transfer to the packaging area.

During the packaging of adhesives an open drum of resin paste was sitting approximately 2 m in front of the workers (for comments on worker exposure see Section 5.2.3). The resin was pumped through pipes into small containers for shipment to customers. The workers placed the small, empty containers into the filling machines and also placed the filled containers into cardboard boxes for subsequent shipment to customers.

Hardeners are formulated and packaged separately in the same manner as described above. A filler is mixed with the hardener so that both the resin and the hardener have approximately the same viscosity. According to one formulator polyamides are the most commonly used hardener for adhesives.

2.5 - End Usage Formulations

Epoxy resin coatings and adhesives have many applications and are discussed further in Section 4.1, (Table 4.4). Generally solid epoxy resins are used in coatings, molding compounds and, to a lesser extent, in adhesive and laminating formulations. Liquid epoxy resins are used in a wide range of applications including casting, potting, encapsulation, tooling, foams, adhesives, laminates and coatings (Lee and Neville, 1967). Based on the industry survey it is believed that in Ontario liquid resins go primarily into adhesives and electrical applications while the solid forms are used principally by the coatings industry.

Outlined below is a brief description of the main formulation processes involved in producing an epoxy resin system (resin plus curing agent) for some key industries in Ontario, i.e., automotive, construction, reinforced plastics and electrical/communications. The aerospace industry in Ontario is also likely to use substantial amounts of epoxy adhesive in joining aircraft components.

2.5.1 - Automotive Industry

Epoxy resins are present in coatings and adhesives used by the automotive industry in the following applications

- as a car body metal primer

- as an adhesive for numerous small applications, e.g., sealing nut/bolt assemblies, sealing flanges, smoothing and sealing car body joints, etc

- as a filler (epoxy putty paste) in body shops.

In the case of the first application mentioned above, in one Ontario plant, car bodies were moved mechanically along hoists in a see-through booth and dipped in a solution typically containing 10 percent liquid epoxy, pigment, a high volume of water, some solvents, and a tin-based catalyst to effect a cure. The epoxy resin is delivered by tanker and pumped into an inside storage tank. From there it is pumped into tanks in the see-through booth and mixed with the other materials. This is an automated process and no workers stand close to the tank. After car bodies are mechanically dipped into the solution, they are rinsed, sanded and then continue along the assembly line to the baking oven. The only area where there are workers continually exposed to the solution is when the car body enters the sanding area after being dipped in the primer and rinsed. In the sanding area there were two

workers wearing cloth and leather gloves. There have been no complaints of dermatitis in this area and it is believed by management that the amount of epoxy resin present in the solution is not significant enough to present a potential problem to the workers. Other worker exposure may occur when someone carries out routine maintenance, e.g., checking the mist nozzles in the rinsing booth.

In another area of the plant epoxy adhesive was being applied to the metal of car body tops that will eventually have vinyl covers. The purpose is to smooth and seal joints. There was no odor from the epoxy adhesive and the worker was wearing one glove. He stated that he has never had a skin rash from working with this material. The premixed adhesive is pumped as required from a small feeder line located near the car assembly line and applied with a small, flat metal tool. There is no local exhaust ventilation and no noticeable odor or vapours. Air sampling has not been carried out in this situation.

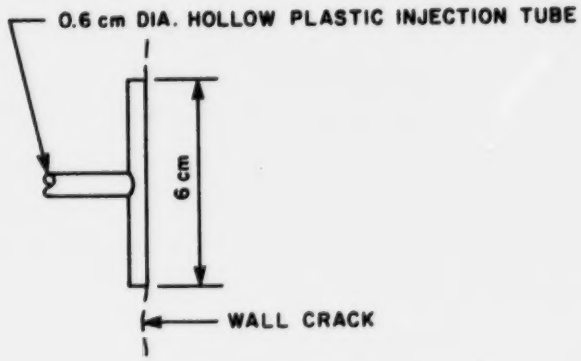
2.5.2 - Construction Industry

Formulations used by the Ontario construction industry may be in the form of a one-container resin cartridge (resin plus curing agent with a seal separating them) or as separate components which require hand or machine mixing of the resin with the curing agent. Some typical applications in the Ontario construction industry follow.

(a) Structural Repair of Cracked Concrete (e.g., bridge decks, parking garages, residential basements)

Repair of a residential basement wall crack was observed. Small, plastic injection tube "tees" as

shown below were placed over the crack approximately 10 to 12 cm apart along the crack, using an automotive body filler for adhesion.



An epoxy sealer was then spread with a plastic spatula along the crack, leaving only the small plastic injection tubes open to the crack. The resin (thick paste) and curing agent (polyamine) components were mixed by hand on a metal tray using rubber gloves. Rubber gloves are also used when applying the sealer. The entire process to this point took about 2 hours. Seventy-two hours later the worker returned to the site to inject a liquid epoxy resin into the plastic tubes along the crack. In this case the liquid resin and the curing agent were poured into 11-L (2.5-gal) metal containers in an outside environment (this process may also be done in the basement) by a worker wearing rubber gloves. The containers were closed and compressed air was forced into the resin and curing agent through separate feeder lines. The feeder line hose was placed into the basement through an open window. At the end of the feeder line there is a static mix tube which mechanically mixes the resin and curing agent before it comes out of the line and is injected into the plastic tubes along the crack. The worker wore rubber gloves and a long-sleeved shirt to avoid skin contact with the resin. There was some dripping

from the feeder line and also from overflow out of the plastic tubes at the crack. There was also a slight odor from the polyamine curing agent in the resin collected in a cup used to catch the drips from the epoxy resin system being injected into the crack. The vapours tended to become more noticeable as curing proceeded but in view of the very small quantities that may drip into the cup, the vapours in this case likely presented a low hazard to the worker.

(b) Epoxy Floors

Although the laying of epoxy floors was not observed, a construction worker who regularly performs this type of work described the process. An epoxy resin system is formulated in an open container using typically 23 L (5 gal) of epoxy resin and 4.5 L (1 gal) of curing agent. A filler is then added and it is mixed mechanically or with a wooden or metal stirrer. A steel trowel is used to lay the epoxy floor. Rubber gloves, a long-sleeved shirt and long pants are recommended by the company performing the work to avoid skin contact with the resin. Nuisance odor masks (containing a charcoal filter) are used, although these masks were not designed by the manufacturer for organic vapours.

(c) Wall and Floor Tile Adhesives

Although this application was not observed, the formulation of an adhesive paste for fixing tiles to concrete walls or floors is similar to that described in (b) above.

(d) Grouting of Ground Anchors

The Ontario construction industry also reported use of an epoxy resin cartridge for grouting of ground anchors. In this situation the resin cartridges are burst at the bottom of a drilled hole and therefore workers do not come into direct contact with the resin or curing agent.

2.5.3 - Reinforced Plastics Industry

In one Ontario reinforced plastics plant visited epoxy resins were used in the following ways.

(a) Formulation of Adhesives

Adhesives are formulated as required (e.g., once a week or every 2 weeks) for use in gluing polyester pipe flanges. In this case a liquid resin drum is opened and a worker places it under a mechanical agitator. The worker hand shovels a powdered filler into the container of liquid resin as the mechanical agitator is operating. This procedure takes anywhere from 30 minutes up to 2 hours depending on the batch size required. The worker was wearing no protective equipment on the face or hands but an elephant trunk air extractor was operating over the open container to collect filler dusts. Ceiling air fans and open doors provided general plant ventilation. No air sampling was reported to have been done.

(b) Application of Epoxy Adhesive to Pipe Flanges

In this situation a worker mixes a small amount (up to 0.5 kg) of epoxy resin paste (liquid DGEBA resin plus filler) with 40 mL of a polyamine (or polyamide) curing agent in a small, open pail

using a wooden or metal spatula. (Larger batches of adhesive cannot be made up at one time because the pot life [i.e., time to cure] is approximately 30 minutes.) The worker then uses the spatula to apply the resin system to the pipe flange. Neither respirators nor local ventilation are considered necessary by the company due to the very small batches used, virtually no odor, and the periodic nature of the operation (i.e., a full 8-h shift but not every day), depending on orders received. No gloves were used by the worker applying the adhesive (although they are available) and it was observed that some of the resin got on his hands. This was subsequently wiped off using acetone solvent and a cloth. This same cloth was occasionally used by the worker to cover his fingers as he smoothed out the adhesive around the flange. The length of time required for a worker to glue a flange varies from 5 to 15 minutes depending on the size of flange. Epoxy resins are also used to glue pipe elbows in this plant.

(c) Laminating of
Epoxy Resin Pipe

This process was not observed since the company rarely produces epoxy resin pipe, primarily because it is more expensive than polyester resin pipe. Also, polyester pipe is more corrosion resistant. The company's last order for epoxy resin pipe came from CIDA who required irrigation pipe for Bangladesh. Polyester pipe manufacture was observed which involves a similar process to epoxy resin pipe manufacture, i.e., a laminate is prepared by alternately layering glass and resin. Workers in the plant visited used long-handled rollers to brush on the resin to the pipe but many had no face protection. Two workers were wearing

dust masks and these workers were previously advised by management that the masks were not effective against organic vapours. Ceiling air fans and open doors comprised the general ventilation where pipes were manufactured but there were no local exhaust fans in the area.

(d) Other Epoxy-Based Reinforced Plastics Products

There are other specialty applications for epoxy resins in the Ontario reinforced plastics industry, e.g., scuff liners for tractor trailer interiors, etc, but details on these applications were not investigated since it was beyond the scope of this study.

2.5.4 - Electrical/Communications Industries

In the electrical industry, epoxy resins may be used in potting and encapsulation (see Glossary) as well as in powder coatings for electrical parts. Some Ontario coatings formulators make casting resins, powder coatings and encapsulation products for the electrical and communications industries by mixing in flexibilizers, diluents and/or fillers in a large enclosed system or 170-L drums. In addition, some Ontario adhesives formulators make epoxy adhesives for the electrical/communications industries, e.g., for repair of printed circuit boards.

One Ontario producer of electrical parts explained that motor parts, coils, etc, are impregnated with a cycloaliphatic-based epoxy resin as a protective coating and insulation material using vapour pressure impregnation (VPI) tanks. Liquid epoxy resin containing a curing agent is pumped in through pipes to the VPI tanks and the parts are placed into the tank by crane. The tank

is then closed, brought up to pressure and the temperature raised to force the resin into the external surface of the part. Subsequently, the resin-impregnated part is put on a trolley and immediately transferred to an oven for curing.

Where hand spraying of machine parts with a liquid epoxy resin is carried out, the part sits on a grating, below which is an air space and then water. An overhead air flow causes any paint spray to be vented downward toward the water below the worker standing on the grate.

Where powder painting is carried out, electrical parts are hung on a line and moved through a booth where they are electrostatically charged. The powder paint falls down on the part and clings to it. The part then moves in front of a booth with a window where a worker touches it up by hand spraying a powder paint as required. For details on worker exposure see Section 5.3.1.

In the telephone industry, epoxy resins were used to "plug" telephone cables. In this process a two-part resin (DGEBA/novolac resin plus curing agent) was mixed in a can (usually in a manhole) and then poured into an injection gun for subsequent injection inside the cable. This resin is no longer used for this purpose by the telephone industry in view of documentation on health hazards obtained by the Communications Workers of Canada (Cwitco, 1984) (see Section 8, Table 8.4). However, the Ontario communications industry still uses some epoxy resins in small amounts during manufacture of transformers, potting of rotary dial spring mounts, and for bonding repair of printed circuit board wire. It could not be determined whether a DGEBA/novolac resin was still being used in these latter applications.

3 - CURING AGENTS, DILUENTS AND FILLERS

3 - CURING AGENTS, DILUENTS AND FILLERS

3.1 - Curing Agents

The conversion of a liquid epoxy resin to a tough solid is accomplished by the addition of a chemically active compound known as a curing agent or hardener. Curing agents are effective in this role by two processes:

(a) conversion which is the removal of reactive groups

(b) cross-linking whereby molecules are coupled through reactive groups to produce a 3-dimensional network which is the thermoset.

Depending on the choice of curing agent, epoxy resins can be made to harden slowly (several hours) or very quickly (less than 1 minute) at room temperature or elevated temperatures (Dowd, 1968).

Curing agents used in Ontario generally fall into one of the following classes--aliphatic amines, aromatic amines, anhydride hardeners, and catalytic curing agents. A general description of these classes follows, with specific attention to those curing agents in each class which are known to be in use in Ontario. An expanded list of potential curing agents for use with epoxy resins is contained in Appendix III.

3.1.1 - Aliphatic Amines

The most common unmodified aliphatic amines used as epoxy resin hardeners are diethylenetriamine (DETA) and triethylenetetramine (TETA), both known to be used in Ontario for curing resins in coating and adhesive applications. Aliphatic amines are the most common

ambient temperature curing agents for epoxy resins and this group also includes ketimines, adducts of epoxy resin and aliphatic amines, and amine-terminated polyamides (Velten, 1975).

Other aliphatic amines identified as being used in Ontario are aminoethylpiperazine (AEP) (provides superior impact resistance compared with DETA and TETA), and polyglycol diamine.

3.1.2 - Aromatic Amines

The advantages of aromatic amines over aliphatic amines for curing epoxy resins are that they allow the cured product to be exposed to higher temperatures without distortion from heat, the resin system has a longer pot life, and the resins have greater resistance to chemicals after cure (Perez, 1968). Aromatic amines are much less reactive than aliphatic amines and usually require elevated temperatures to achieve a proper cure (Velten, 1975).

Aromatic amines identified in the Ontario survey were 4,4'-diaminophenyl sulfone (DDS), 4,4'-methylenedianiline (MDA) and dimethylaniline (DMA). Another common aromatic amine for use in epoxy systems is meta-phenylenediamine (MPDA).

3.1.3 - Anhydride Hardeners

Phthalic anhydride, hexahydrophthalic anhydride (HHPA) and nadic methyl anhydride (NMA) are curing agents used with epoxy resins in Ontario.

Phthalic anhydride is inexpensive and, therefore, an attractive choice where cost is the primary factor and overall performance is secondary. Systems employing phthalic anhydride for laminates and castings have

useful but shorter pot lives than epoxy mixtures with other anhydrides (Perez, 1968). Pot life is the time available for use of an epoxy system after the resin and curing agent are mixed.

HHPA-cured epoxies are used in laminating, potting, tooling and industrial coatings and are much more stable electrically than amine-cured epoxies. NMA is commonly used for electrical laminating and filament-winding applications (Perez, 1968).

Other anhydride curing agents used with epoxy resins (but not identified in the Ontario survey) include dodecenylsuccinic anhydride (DDSA), tetrahydrophthalic anhydride (THPA), maleic anhydride, pyromellitic dianhydride (PMDA), chlorendic anhydride, trimellitic anhydride (TMA), and other eutectic (easily melted) anhydride mixtures.

3.1.4 - Catalytic Curing Agents

Catalytic curing agents act as initiators and promoters of epoxy resin curing actions but do not participate in the epoxy polymerization reaction. This class includes tertiary amines, amine salts, dicyandiamide*, boron trifluoride complexes and amine borates.

Tertiary amines are used as accelerators for anhydride cures as well as to enable full cure of aliphatic amine-hardened epoxy resins (Perez, 1968). The only tertiary amines identified by Ontario resin users surveyed were 2,4,6-tris(dimethylaminomethyl)phenol (DMP-30) and benzyldimethylamine. Other substances in this group which may be used but were not identified in

*Not a true catalyst since some reaction takes place between the resin and this compound.

the Ontario survey are dimethylaminomethylphenol (DMP-10), ethyl diethanolamine, and α-methylbenzyldimethylamine.

Dicyandiamide and boron trifluoride monoethylamine are considered "latent" catalysts because they can cure epoxies in a short time (e.g., 1 hour) at elevated temperatures after having been mixed and stored for 3 months to 1 year without producing a reaction. Dicyandiamide is used in Ontario with epoxy resins to produce powder coatings for electrical encapsulation. Boron trifluoride monoethylamine is used in Ontario by at least one coatings manufacturer.

3.1.5 - Polyamides (Flexibilizers)

Polyamides are used for room temperature cures when modest flexibility is desired (Nielsen, 1982). Commercial polyamides are made from dimerized or polymerized fatty acids and their reaction products with polyamines (Perez, 1968).

Dimer acid-based polyamides have been identified with the use of epoxy resins in Ontario in adhesive and coatings applications. A product known as "Versamid" is a commonly used polyamide in Ontario which is a reaction product of dimer acids with either diethylenetriamine (Versamid 125) or triethylenetetramine (Versamid 140) (Perez, 1968).

Epoxy resins containing polyamides have better water resistance than some of the aliphatic amines, however, they lack solvent resistance and are not resistant to heat (Perez, 1968).

3.1.6 - Polysulfides (Flexibilizers)

This group includes a variety of mercaptan-containing compounds which are used to give flexibility to the

cured resin rather than being used as hardeners. They are generally used with a catalyst (e.g., DMP-30 and DMP-10) to modify epoxy resins used in plastic tooling, electrical potting, protective coatings and adhesives (Perez, 1968).

An unspecified mercaptan-based product was the only polysulfide identified in the Ontario industry survey and it is being used in epoxy adhesive formulations.

3.1.7 - Amino and Phenol-Formaldehyde Resins as Curing Agents

Urea-formaldehyde and melamine-formaldehyde resins are classed as amino resins which are generally reacted with DGEBA resins to produce epoxy resin coatings for appliance finishes, drum linings and decorative finishes. Urea-formaldehyde/epoxy systems provide the best color and melamine-formaldehyde/epoxy systems provide greatest flexibility and impact resistance (Lee and Neville, 1967).

Phenol-formaldehyde resins are usually used with DGEBA resins to produce epoxy resin systems for corrosion-resistant piping, electrical coatings and collapsible tube coatings (Lee and Neville, 1967).

Both amino and phenol-formaldehyde resins are used in the Ontario epoxy resin industry, especially for can coatings, where a "solventless" or waterborne system is preferred.

3.2 - Diluents/Solvents

Diluents are added to an epoxy resin system primarily to reduce viscosity. They may also be used to modify properties of the cured resins, e.g., improve chemical resistance, change electrical properties, impart flame resistance, or

possibly change impact resistance and physical properties to a limited degree (Lee and Neville, 1967).

Diluents are usually divided into two basic categories: reactive and nonreactive.

3.2.1 - Reactive Diluents

Reactive diluents contain a chemical group which will react with the epoxide groups in the resin. A common reactive diluent associated with epoxy resins in Ontario is n-butyl glycidyl ether. Other typical reactive diluents used with epoxy resins are listed in Appendix III.

3.2.2 - Nonreactive Diluents (Solvents)

Solvents used with epoxy resins in Ontario include acetone, Cellosolve*, glycol alcohol, methyl ethyl ketone, methyl isobutyl ketone, methylene chloride, 1,1,1-trichloroethane, toluene and xylenes. Other common solvents which may be used are listed in Appendix III.

3.3 - Fillers and Pigments

Fillers used in epoxy resins are normally inert, finely divided powders which are employed to control viscosity, reduce shrinkage, and/or effect a cost reduction. It is recommended by Lee and Neville (1967) that fillers be heated to drive off moisture and adsorbed gases before being incorporated into the resin.

*Tradename.

While there are several hundred commercial fillers suitable for use in epoxy resins, those identified in the Ontario industry survey were calcium carbonate, clay (bentonite), silica, and talc.

Particulate fillers may be incorporated into liquid epoxy resin formulations by the use of two-roll mills or screw-type kneaders. If the formulation is a solid, fillers may be blended by the use of a pebble mill and then rolled and ground if desired (Lee and Neville, 1967).

Pigments may also be added to epoxy resin formulations in paste or powder form to add color. Identification of pigments was not part of this Ontario industry survey.

4 - CURRENT AND PROJECTED USAGE PATTERNS FOR EPOXY RESINS IN ONTARIO

4 - CURRENT AND PROJECTED USAGE PATTERNS FOR EPOXY RESINS IN ONTARIO

4.1 - Current Usage Patterns

It is estimated that approximately 3,400 tonnes of epoxy resins (solid and liquid) are used in Ontario annually (see Table 4.1). This estimate is based on one formulator's knowledge of the Ontario industry who suggested that Ontario's usage represents approximately 40 percent of national demand. No other estimates were submitted from the industry during the survey. Statistics for Canada are available from Corpus (1981). The breakdown in Table 4.1 is based on data on epoxy resin usage from the Ontario coatings industry and the assumption that the remainder is used in adhesives applications.

Table 4.2 provides a breakdown of Ontario use by epoxy resin type, and Table 4.3 provides an estimate of curing agent quantities used in epoxy resins. Both tables are based on information gathered during the industry survey.

Typical applications for epoxy resins used in Ontario are shown in Table 4.4. The various types of epoxy resins are used in similar applications; however, the range in properties of a specific type of resin may limit its application to a particular use. For example, DGEBA resins are limited to indoor electrical application due to poor wet arc-track resistance and UV resistance; cycloaliphatic resins cured with a nonaromatic anhydride hardener (e.g., hexahydrophthalic anhydride) are the choice for outdoor electrical applications and are used for insulators, switchgear components and instrument transformers (Kirk-Othmer, 1980).

Similarly, epoxy novolac resins may be preferred over DGEBA resins because of high temperature performance and good strength and chemical resistance, although they cost more. In June 1984, liquid DGEBA resins selling in Ontario were

TABLE 4.1

ONTARIO EPOXY RESIN
USAGE PATTERNS (1981)

Market	Estimated Usage Tonnes	% of Total
Coatings (for automotive primers, tank and drum linings, pipe coatings, electrical coatings, epoxy floors, etc)	2 390*	70
Adhesives (for aerospace, construction, electronics and reinforced plastics industries)	1 010	30
TOTAL	3 400	100

TABLE 4.2

ONTARIO EPOXY RESIN
USAGE BY TYPE (1981)

Resin Type	Estimated Usage Tonnes	% of Total
DGEBA resins	2 975	88
Novolac resins	300	9
Cycloaliphatic resins	50	1
Brominated resins	50	1
Flexibilizing resins	25	<1
TOTAL	3 400	~100

*Canadian Paint and Coatings Association data. (Does not include 487 tonnes of epoxy esters.)

TABLE 4.3

ESTIMATED 1982 ONTARIO USE
OF CURING AGENTS IN EPOXY RESINS

Chemical Compound	Approximate Amount Used (tonnes)
Polyamines	
Diethylenetriamine (DETA)	10
Triethylenetetramine (TETA)	12
Aminoethylpiperazine (and derivative adducts)	2
4,4'-diaminodiphenyl sulfone (DDS)	2
4,4'-methyldianiline	0.3
m-phenylenediamine	0.05
Others	0.5
Polyamides	150
Anhydrides	
Phthalic anhydride	400
Nadic methylanhydride	5
Hexahydrophthalic anhydride	12
Amino/Phenol Formaldehyde Curing Agents	
Melamine formaldehyde	70
Phenol formaldehyde	60
Urea formaldehyde	75
Catalytic Curing Agents	
Dicyandiamide (Dicy)	5
Boron trifluoride monoethylamine (BF_3MEA)	5
Benzyldimethylamine	0.1
Others (including DMP-30)	80

TABLE 4.4

TYPICAL USES FOR EPOXY RESINS IN ONTARIO

DGEBA Resins

Protective coatings
- metal primers
- maintenance coatings
- floor coatings
- appliance primers
- marine coatings
- computer finishes
- aircraft primers

Adhesives
- bonding dissimilar materials
- bonding organic or inorganic particles
- bonding plastics, metal or glass

Construction industry
- concrete repairs
- bridge construction (joining concrete segments)
- grouting

DGEBA Resins (cont)

Castings
- indoor electrical applications (e.g., transformers, encapsulated coils)
- molding tools (e.g., aircraft, foundry and automobile applications)

Compression molding (e.g., pump housings, impellers, pipe fittings, valves)

Reinforced composites
- epoxy/glass composites for pipe in oil, gas, mining and chemical industries
- epoxy resin - glass laminates for electronics industry, sports equipment, battery cases, repair of plastic auto bodies, aircraft fabrications

High-Molecular-Weight Bisphenol A Resins

Transportation industry
- epoxy esters for automotive primers

Other industries
- tank linings
- can and drum coatings
- pipe coatings
- decorative coatings

Epoxy Novolac Resins

Structural laminates
- filament wound pipe

Electrical laminates
- printed circuit boards

High-temperature adhesives

Electrical encapsulation

Electrical varnishes

Lab countertops

Molding powder

Corrosion-resistant coatings

Flexibilizing Epoxy Resins

Adhesives

Encapsulation of electrical components

Diluent in tooling compounds

Brominated Epoxy Resins

Flame-retardant applications
- structural laminates (e.g., filament wound pipe)
- electrical laminates (e.g., printed circuit boards)
- electrical potting and encapsulation
- adhesives
- coatings

Cycloaliphatic Epoxy Resins

Electrical insulators

Encapsulations for transformers, motors and coils

Coatings

$3.87/kg while the solid DGEBA resins sold for $3.66/kg. This compared with a price of $5.98-6.69/kg for epoxy-phenol novolacs (Dow Chemical, 1984b). Alternatively, DGEBA resins can be upgraded with epoxy novolac resins, as has been done for electrical applications, e.g., coils, capacitors, transformers, ignition coils, etc.

4.2 - Future Trends

Based on discussions with industry representatives, it is anticipated that there will be an annual increase of approximately 5 percent in epoxy resin use over the next 5 years. Some of this increase may be attributed to recent market developments. For example, as the cost of organic solvents rises and legislation accelerates regarding solvent emissions, research efforts into the use of water-based epoxy resin systems have also increased (Kirk-Othmer, 1980; Vail, 1981; Richardson, 1982). Water-based coatings utilize either liquid or solid epoxy resins that have been modified to allow their use with water. Emphasis on research has been to develop systems particularly suitable for automobile and container applications (Kirk-Othmer, 1980).

Future trends in other areas include the use of a one-component epoxy resin-based solder to replace conventional lead solders; the use of epoxy adhesives in high pressure refrigeration coils, dehumidifiers and air conditioners; and expanded use of epoxy resins and hardeners in reinforced plastics, especially in filament winding (Kent, 1983).

More specific information on 250 new processes during the period January 1980 to mid-1981 is documented in the reference handbook on Epoxy Resin Technology Developments since 1979 (DiStasio, 1982). These new developments are in the following areas.

(a) Powder coatings
- new curing agents and accelerators
- new powder coating compositions.

(b) Electrodeposition and waterborne coatings
- polyisocyanate and other compositions.

(c) Solvent-based coatings
- new high solids compositions
- new low solvent content compositions
- new general coating formulations
- specialty applications (e.g., weldable coating composition, coating for asphalt surfaces, etc).

(d) Photocurable coatings and printing inks
- epoxy resins capable of quick cure (i.e., in 1 minute or less) following exposure to ultraviolet radiation.

(e) Adhesives, sealants and elastomers
- new elastomeric compositions, sealants, adhesives, solder and repair putty compositions.

(f) Molding and laminating compositions and fiber impregnation techniques.

(g) Synthesis of various epoxy resins and epoxy products.

(h) New curing agents
- amine hardeners
- anhydride and acid hardeners
- other catalysts.

(i) Electrical applications
- new electrical molding, insulating and laminating compositions
- new sealants

- new electrical applications, e.g., electrically conductive adhesive, strippable solder composition, etc.

(j) Advances in specialty applications
- ion exchange and chelate resins
- paper and textile processing
- flame retardant compositions
- foamed systems
- other processes, e.g., antifogging treatment for vinyl food wraps, concrete repair composition, solventless traffic paint, etc.

5 - WORKER EXPOSURES AND CONCENTRATIONS IN THE WORK ENVIRONMENT

5 - WORKER EXPOSURES AND CONCENTRATIONS IN THE WORK ENVIRONMENT

The exposures of concern with regard to epoxy resins relate to skin contact with the resins, inhalation of vapours (primarily when mixtures are heated to effect a cure) and particulate dusts during handling of bisphenol A, epoxy resin flakes, and powdered curing agents. Recently concerns have been expressed with respect to products from heating epoxy dust (Goransson et al., 1984).

The results of sampling for concentrations of epoxy resin dusts and bisphenol A dusts in the Ontario workplace are described in Table 5.1. Based on discussions during the Ontario survey, no sampling has been carried out in this province to establish concentrations of curing agent vapours in the occupational environment. This is probably due to the fact that sampling and analytical techniques for many of these substances have not been published and there is insufficient toxicity data available to allow exposure limits to be set in many cases. Also, the range of solvents available is extensive and no details on solvent emissions during epoxy resin formulation or use were available from the Ontario industry survey. General exposure data found in the literature for the epoxy resin industry are documented in Appendix Vb.

Apart from the general discussion on epichlorohydrin below, this section of the report deals with the main formulation processes and usage applications identified in Ontario.

5.1 - Epichlorohydrin (ECH)

Epichlorohydrin has received much attention in recent years by those concerned with worker exposure to hazardous substances in the epoxy resin industry. Traces of unreacted ECH may be present in epoxy resins imported into Ontario and the residual content in epoxy resins is estimated by one researcher to be about 10 ppm (Holland, 1980). In analyses for ECH reported by Consumer and Corporate Affairs Canada,

TABLE 5.1

CONCENTRATIONS OF EPOXY RESIN AND BISPHENOL A DUSTS IN THE ONTARIO WORKPLACE

Process/Location	Exposure	Sampling Location	Duration of Sampling	Particulate Exposure Levels* Average (mg/m^3)	Maximum (mg/m^3)	Reference
Production of solid epoxies	uncured epoxy resin dusts	bagging machine	60 minutes	4.0	10.0	Dow Chemical (Sarnia)
Production of solid epoxies	bisphenol A dusts	dumping bags into reactor	15 minutes	40.0	97.0	Dow Chemical (Sarnia)
Formulation of epoxy esters for coatings industry	uncured epoxy resin dusts	loading of solid epoxy resins into reactor	43 minutes	0.23	-	CIL (Toronto)
User of dry epoxy resins in coatings formulations	uncured epoxy resin dusts	loading of dry epoxy resins into mixers	3.5 to 6.5 hours	0.3**	0.5**	Du Pont (Ajax)

* Exposures are based on actual duration of sampling except where otherwise noted.
**Calculated on basis of 8-h time-weighted average.

various experimental formulations were analyzed. In three samples analyzed, epichlorohydrin was measured at 24 ppm in one and not detected in the other two. The method used was believed to be sensitive enough to detect ECH at the 2-ppm level (Consumer and Corporate Affairs Canada). However, the risk to Ontario workers is believed to be minimal based on limited monitoring carried out by Shell and NIOSH in the United States. Results of the Shell study conducted in a range of environments are shown in Table 5.2. As noted in the latter table it was not possible to detect ECH in the workplace atmosphere at a level of detection of 0.05 ppm. The NIOSH monitoring program was carried out at an electronic component molding operation. Most of the epoxy resins were made from bisphenol A and epichlorohydrin and had to be heated prior to use. Environmental monitoring using charcoal tube and gas chromatography indicated that epichlorohydrin was not present in the air at a level of detection of 0.005 ppm (NIOSH, 1976).

The Ontario survey conducted by Acres indicated that no monitoring for ECH levels has been carried out in this province. An industrial hygiene survey is necessary to confirm that there is little or no hazard in this province. This survey should include both the large formulators and smaller companies which import liquid resins directly.

5.2 - Formulation Processes

5.2.1 - Production of Solid Epoxy Resins (Flakes)

The primary concerns regarding worker exposure during the production of solid epoxy resins relate to dusts both when operators dump bisphenol A into the reactor and during bagging of the solid resin flakes. At Dow's Sarnia facility these operations are carried out once per 12-h shift and require approximately 15 minutes to dump the bisphenol A into the reactor; approximately 1 hour is required for bagging of the solid resin flakes.

TABLE 5.2

OCCUPATIONAL EXPOSURES TO
EPICHLOROHYDRIN DURING USE OF EPOXY RESINS
(Berger et al., 1980)

Application and Job Categories Sampled	Personal Monitoring Interval	Airborne ECH Concentration
Coatings Manufacture		
Mixer	320 minutes	ND*
Packager	307 minutes	ND
Packager	313 minutes	ND
Laboratory Technician	83 minutes	ND
Filament-Wound Pipe		
Oven Operator	6 to 7 hours	ND
Fitting Machine	6 to 7 hours	ND
Glassman	6 to 7 hours	ND
Winding Machine	6 to 7 hours	ND
Storage Tank Lining		
Sprayer	331 minutes	ND
Hose Handler	328 minutes	ND
Roller	327 minutes	ND
Pump Operator	285 minutes	ND
Encapsulation		
Operator	415 minutes	ND
Compounder	398 minutes	ND
Compounder	399 minutes	ND
Press Operator	460 minutes	ND
Chemist	433 minutes	ND

*Denotes none detected at a detection limit of 0.05 ppm.

During dumping of bisphenol A into the reactors, average airborne concentrations of 40 mg/m^3 have been measured over the 15-min operation, with maximum concentrations of 97 mg/m^3. Average exposures to solid epoxy resin dusts at the bagging machine were found to be 4 mg/m^3 during the 1-h operation with maximum concentrations of 10 mg/m^3 (Dow Chemical, 1983). Respirators (3M No. 8710), safety glasses and disposable coveralls are mandatory at Dow's Sarnia plant for dusts during dumping of bisphenol A into the reactor. The company provides respirators for use on an optional basis in the solid epoxy resin bagging area, and gloves are optional for all operations. For information on engineering controls see Section 8.1.

5.2.2 - Coatings Manufacture

Worker exposure to epoxy resins in the coatings industry can occur when performing the following activities

- transfer of liquid resin from tank car to inside storage tanks

- dumping of solid or liquid resin into ball, pebble or sand mills, or into a reactor

- sample testing for laboratory analysis

- cleaning of the filter press (epoxy esters)

- packaging of the end product

- general clean-up maintenance.

The nature of potential exposure will be skin contact with liquid resin, or inhalation of epoxy resin dusts when dumping bags of epoxy resin flakes. However, batches of epoxy resin-based coatings are not made up

on a continuous basis but in accordance with demand which may result in 10 to 12 batches per year on average.

Generally exposures of more concern to companies in the coatings industry relate to pigment and filler dusts, as well as the organic vapours from solvents and curing agents. All of the latter materials are used in epoxy-based coatings. To obtain a better understanding of areas for potential worker exposure in the various applications for epoxy resins in the coatings industry, see the process descriptions (Section 2.4.2).

Sampling results for concentrations of uncured epoxy resin dusts were obtained from two coatings formulators as shown in Table 5.1.

5.2.3 - Adhesives Manufacture

During the formulation of an epoxy resin paste (liquid resin plus filler) the only noticeable exposure experienced by the mixing operator was to the dusts when the filler was being added to the open container of resin. This operation takes about 30 minutes and an elephant trunk dust extractor was operating over the open container at the adhesives plant visited. Also, the worker was wearing a dust mask. There was no apparent odor or vapour from the liquid resin and, although the worker was wearing cotton gloves, it would be a rare occasion that he would come into contact with the resin since the containers are moved by machinery from weigh scales to the mixing area.

In a separate operation a curing agent formulation (curing agent plus filler) is prepared in a similar manner to the epoxy resin paste. Although formulation of the curing agent mixture was not observed, it is expected that the worker would be exposed for a brief

period (30 minutes) to curing agent vapours and filler dusts when adding filler to the curing agent. Alternatively, if powdered curing agents are used, the exposure would be to dusts only. The total amount of time spent by a mixing operator performing these tasks would average approximately 1 hour in an 8-h working day.

Another area of potential exposure occurs during packaging operations when workers may accidentally have skin contact with the resin or curing agent or breathe in the curing agent vapours. In the plant visited, it was observed that the open containers of resin and curing agent were sitting approximately 2 m away from the packaging operators. The workers do not work over the open containers; the resin and curing agent are pumped separately to packaging machines located a few metres away from the containers. While packagers (up to 3 per machine) may work at this task for a full 8-h shift, packaging is usually carried out on an intermittent basis, e.g., 1 day every 2 to 3 weeks.

One adhesives formulator suggested that the main exposure is likely to occur during cleanup of equipment, however, no clean-up procedures were observed in the plant visited.

No air monitoring associated with epoxy resins is presently carried out by any of the three adhesives formulators contacted during the Ontario industry survey.

5.3 - End Usage Applications

5.3.1 - Powder Coatings

During the application of epoxy resin-based powder coatings (e.g., automotive and electrical industries),

workers may be exposed to nuisance dusts when the excess powder is blown off with compressed air after the coated object is removed from a fluidized bed. There may also be exposure to curing agent vapours on removal of the object from the fluidized bed, if the object being coated was preheated prior to dipping in the fluidized bed. Since no plants visited were using powder coatings, the extent of exposure in Ontario is unknown.

If the powder paint is applied using an electrostatic charge, exposure to dusts is likely, particularly during touch-up operations when hand spraying powder paint into the booth. Respirators are usually mandatory in this type of situation.

5.3.2 - Solution Coatings

During application of epoxy resin-based solution coatings in Ontario (e.g., can and drum linings, pipe coating, structural steel coatings, marine finishes, etc), workers may be exposed to vapours associated with curing agents and solvents in the coatings mixture. Where solventless or waterborne systems are used, exposures to curing agents such as urea formaldehyde, melamine formaldehyde, and phenol formaldehyde resins would be the primary concern.

In an automotive plant where solution coatings were being applied, the operation was carried out in an enclosed booth. The only worker exposure to the epoxy-based solution would be during routine maintenance or in the sanding area after the car body has been coated and rinsed (see Section 2.5.1).

5.3.3 - Construction Industry

Based on the Ontario industry survey, exposures will occur primarily during mixing of a 2-part epoxy resin

(resin and curing agent) for concrete repairs and grouting. One building repair contractor advised that fair-haired and red-haired employees were particularly susceptible to rashes when working with epoxy resins. Another contractor advised that a number of his employees had an allergic reaction after working with epoxy resins and have since been transferred to other types of construction work.

The use of epoxy adhesives in fixing tiles to concrete walls and floors may also produce exposures if the resin and curing agent are mixed in an open container, and during application of the adhesive. One procedure described by Hosein (1980) indicates that after drying, the epoxy resin grout is smoothed over the tile using a cloth soaked in hot water. Skin contact would be the primary hazard. This hazard may be compounded by the use of rags dampened in hot water.

For further details on worker exposure in the construction industry see Section 2.5.2.

5.3.4 - Reinforced Plastics Industry

In the reinforced plastics industry, exposures can occur during application of the liquid resin and curing agent mixture to the glass layers (see Section 2.5.3). Also, subsequent grinding of the finished laminated product will produce exposures to cured epoxy dusts.

Evidence of dermatitis has been documented by a number of researchers reporting on exposures during fabrication of reinforced plastics, e.g., lamination of ski sticks (Suhonen, 1983), manufacture of plastic tennis racquets (Lachapelle et al., 1978), and gluing of glass fibers (Gaul, 1967). Also, respiratory problems have been encountered from exposure to curing agents in resins used in the reinforced plastics industry (see Appendix Vb).

Since adhesives are formulated and used in the reinforced plastics industry, this is another area for potential worker exposure (see Section 2.5.3).

5.3.5 - Electrical/Communications Industries

Exposures will vary considerably in this industry sector because of the wide range of operations, e.g., pouring of liquid castings, encapsulation of electrical components, and liquid and powder painting of parts.

One Ontario plant producing electrical products indicated that exposures would occur as a result of inadvertent splashing or dripping and possibly from vapours during opening of the vapour pressure impregnation tanks to "dip" the motor parts and coils. However, local ventilation is used to draw any vapours away from the workers, and operators wear respirators and face-shields, as well as gloves and aprons. In another area, wire coils are wound by hand and by machine with epoxy impregnated tape. These workers wear cotton gloves with leather inserts as well as aprons, goggles and smocks.

During application of liquid epoxy paints in the same plant, a machine part is spray-painted in an area with good local ventilation where air is drawn away from the breathing zone. General ventilation is also present in this area.

In another operation where switchgear parts are powder-painted using an electrostatic charge, the worker wears a respirator but no glasses. Glasses tend to get clogged with powder quickly and the worker indicated that he did not experience any eye irritation. There is both local and general ventilation in this area of the plant.

An Ontario communications facility advises that exposures encountered are as a result of skin contact with the resin at time of mixing. However, much of the epoxy is dispensed from "B-PAX" dispensers containing the resin and curing agent which create no exposure on mixing. Some minor exposure to vapours is likely when bonding adhesives are applied from 0.5-mL vials.

5.4 - Ontario Workers at Risk by Industry Sector and Occupational Category

Table 5.3 identifies workers at risk by industry sector and occupational category at the "secondary manufacturer" stage, i.e., where imported epoxy resins are modified in some manner prior to being shipped to end users. The number of workers potentially exposed at the "end user" stage in industrial applications has been estimated at 10^3 to 10^4 by one formulator. Dow Chemical (1984) advises that less than 5 percent of all resin sales represent small tubes of liquid epoxy resin and hardener used by the general public.

TABLE 5.3

WORKERS WITH POTENTIAL EXPOSURE TO EPOXY RESINS, BISPHENOL A AND/OR ASSOCIATED CURING AGENTS AND DILUENTS IN ONTARIO*

Ontario Producer/ Formulator	No. of Workers	Duration of Exposure
Dow Chemical (solid epoxies)		
- Process operators	11	10 percent of shift
- Maintenance workers	5	5 percent of shift
- Supervisors	5	Walk-through
Coatings Formulators**	625***	
- Resin kettle operators/mixers		Partial shift when batches operating
- Fillers		Partial shift as required
- Maintenance		Walk-through
- Supervisors		Walk-through
Adhesives Formulators**		
- Mixing vessel operators	40	Partial shift
- Weighers	20	Partial shift
- Packagers	60	Partial to full shift but not every day
- Maintenance	20	Walk-through
- Supervisors	20	Walk-through
TOTAL	806	

* This table includes potential exposures by workers involved in preparation of formulations; it does not include end users of product, e.g., automotive, electrical, communication, reinforced plastics, construction, etc. Insufficient data were available to allow a breakdown by occupational category.

** Includes coatings and adhesive formulators who also produce casting resins, coatings and adhesives for the electrical, communication, automotive, reinforced plastics and construction industries.

***Canadian Paint and Coatings Association (based on 1981 data).

6 - HEALTH EFFECTS

6 - HEALTH EFFECTS

This section deals with the health effects associated with cured and uncured epoxy resins as well as curing agents, diluents and fillers. The large number of compounds investigated in this study necessitated a general overview of health effects rather than an in-depth study of individual compounds. Since the majority of epoxy products imported into Ontario are DGEBA resins, their main constituents, i.e., epichlorohydrin and bisphenol A are discussed briefly in the subsections below.

The principal acute health effect associated with epoxy resins is contact dermatitis as indicated by a number of documented reports in various industry sectors (Appendix Va). In many instances the references for these reports did not indicate the components of the epoxy resin or the authors were unable to specify which constituent(s) of the resin caused the dermatitis. However, Firmingham (1969) indicated that most components of an epoxy resin system produced varying degrees of dermal irritant action.

Other acute effects reported in the literature (Appendix Vb) are associated with respiratory tract symptoms (e.g., mild nasal irritation, asthma attacks), hemolytic anemia and eye irritation due to vapours or dusts from the various resin components. The case study reports listed in Appendix Vb suggest that respiratory tract symptoms are generally associated with epoxy resin powder formulations used in coatings applications and associated with cured epoxy resin dusts used in the reinforced plastics industry.

The chronic effects of epoxy resins are not well defined. Nothing was found in the literature to suggest that solid epoxy resins have a carcinogenic potential. However, based on a number of animal studies summarized by Berger et al. (1980) (Appendix Vc), the evidence is inconclusive regarding

the carcinogenicity of liquid DGEBA resins. It must be emphasized, though, that one of the major problems with many of the studies carried out to date is that the epoxy resins were not carefully characterized chemically; also they were not representative of epoxy resins currently manufactured which are believed to have fewer impurities (Berger et al., 1980; Hine et al., 1982). More recent animal tests with liquid DGEBA resins by Holland et al. (1981) and Shell/Ciba-Geigy (Shell, unpublished) indicate no carcinogenic activity. The work by Holland et al. (1981) involved skin application to mice of DGEBA resins from three manufacturers at a rate of 75 mg/wk for 2 weeks and an observation period of 2 years. The Shell/Ciba Geigy studies involved two 2-yr mice skin painting experiments using commercial DGEBA resins. A slightly higher incidence of tumors over controls was not statistically significant in one experiment (Shell, unpublished); the other experiment indicated no increased incidence of tumors when compared with controls (Holland et al., 1981). There is, however, an indication that the combination of epoxy resins with other resins or reactive diluents may present an enhanced potential for carcinogenic response (Berger et al., 1980; Holland et al., 1981).

Mutagenicity tests using liquid and solid epoxy resins produced mixed results. Hine et al. (1981) (Appendix Vd) summarized the results of mutagenicity tests and found 18 positive and 23 negative. These mixed results and research by Cummins et al. (Cummins and Marck, unpublished; Cummins, unpublished; Murray and Cummins, 1979) suggest that some epoxy resins may have the potential to cause genetic changes. Also, one study of workers occupationally exposed to epoxy resins found a significant increase in chromosome aberrations (Suskov and Sazonova, 1982). The epoxy resin in the latter study was manufactured from epichlorohydrin and diphenylolpropane. However, another study by Mitelman et al. (1980) found no evidence of an increase in chromosomal aberrations in workers exposed to DGEBA resins.

No studies were found in the literature of carcinogenicity or teratogenicity as a result of occupational exposure to epoxy resins. The bulk of the computerized literature searches for this background document were conducted during August, September and October 1983.

6.1 - Epichlorohydrin

While it is not known whether epichlorohydrin is even detectable in the Ontario occupational environment where epoxy resins are formulated or used, its potential as a serious health hazard warrants a brief discussion.

Effects of epichlorohydrin on humans include burning of the eyes and nasal passages at 20 ppm, severe chemical burns on skin contact and a possible contact dermatitis, or skin sensitization (NIOSH, 1978). NIOSH advises that worker risks from exposure to epichlorohydrin may also include respiratory cancer based on one study of workers at Shell Chemical Company (Enterline, 1978a). There is also evidence of mutagenicity in humans based on a significant increase in chromosomal aberrations found in the white blood cells of workers occupationally exposed to epichlorohydrin (Kucerova et al., 1977). However, there is some disagreement regarding the effects of epichlorohydrin on sterility. While NIOSH (1978a) quotes one experiment that induced sterility in rats, a number of researchers have found no detrimental effects based on sterility studies of male workers (Venable et al., 1980); Milby and Whorton, 1980; Milby et al., 1981).

Laboratory experiments with rats exposed to epichlorohydrin have produced nasal cancers following exposure to 100 ppm, for 6 h/d, 5 d/wk for 30 days (N.Y. University Institute of Env. Medicine, 1978). Further, high concentrations of epichlorohydrin (100 ppm) can lead to fluid in the lung and kidney problems in test animals although the length of exposure and animal type were not specified (NIOSH, 1978a).

6.2 - Bisphenol A

Animal studies indicate that bisphenol A is of low toxicity orally, and exhibits minimal eye and skin irritation (Boiano, 1981). It is, however, capable of causing skin sensitization reactions on repeated contact (Krajewska and Rudzki, 1976; Boiano, 1981).

Unusual sensitization reactions were recorded by Allen and Kaidbey (1979), and by Goransson et al. (1984) suggesting that the bisphenol A component of a heated epoxy resin - diluent mixture was responsible for causing a persistent photosensitivity reaction. Over 4 years after accidental exposure, affected persons were still photosensitive (see Appendix Va).

Bisphenol A tested in the Ames test was found not to be mutagenic with or without the addition of liver microsomes (Andersen et al., 1978). No information was found on the carcinogencity or teratogenicity of bisphenol A.

6.3 - Uncured Epoxy Resins

Most reports in the literature address DGEBA resins; however, any available documentation on the health effects of other resin types is also included in this section.

6.3.1 - DGEBA Resins

Both the liquid and solid DGEBA resins have a low potential for acute toxicity by all routes of administration, but in general the potential for acute toxicity increases as molecular weight decreases; none of these resins are volatile and therefore exposure by inhalation is not a serious hazard (Hine et al., 1982). However, when curing agents and diluents are used with epoxy resins, inhalation of these more volatile compounds becomes a more serious hazard and adequate ventilation is required.

Skin irritation is the primary concern with uncured DGEBA resins. The resin rather than the hardeners and reactive diluents has now been implicated as the main cause of allergic contact dermatitis (Calnan, 1958; Zschunke, 1959; Malten, 1964; Thorgeirsson et al., 1975; Rudzki 1981; Adams, 1983), particularly the MW340 oligomer* component of resins (Thorgeirsson and Fregert, 1977; Fregert and Thorgeirsson, 1977; Thorgeirsson et al., 1978). However, this was disputed in earlier studies by Lea et al. (1958) who suggested that the hardeners were more likely to cause dermatitis than epoxy resins. In any case, most resin system components produce varying degrees of skin irritation.

Other than recurring skin irritation, no adverse effects of a chronic nature have been reported in the occupational environment. Carcinogenicity and mutagenicity of epoxy resins have been discussed previously.

No studies were found in the literature of carcinogenic or teratogenic effects as a result of occupational exposure to DGEBA resins.

6.3.2 - Brominated Epoxy Resins

The hazards associated with these resins are essentially the same as those for DGEBA resins except that in the event of combustion, bromine and hydrogen bromide vapours may be released (Hine et al., 1981).

*The smallest molecule of DGEBA resins has a low molecular weight of 340 and the sensitizing capacity seems to be greater with the lower molecular weight resins.

6.3.3 - Epoxy Novolac Resins

The phenolic and cresolic novolac resins appear to have a low potential for acute toxicity by oral and dermal routes. Phenolic novolac resins are minor skin irritants on single contact but more appreciable irritation can develop after prolonged or repeated contact. Both novolac resins can cause minor transient eye irritation (Hine et al., 1981).

6.3.4 - Cycloaliphatic Epoxy Resins

Documentation was found on the health effects of only one cycloaliphatic epoxy resin, bis(2,3-epoxycyclopentyl) ether. Mixed results have been obtained with carcinogenic tests performed on mice (Weil, unpublished data, no date). With regard to mutagenicity, results were positive in the Ames test, positive in a cell transformation assay in Chinese hamster ovary cells, and negative for induction of DNA repair in cultured human leukocytes (Oak Ridge National Laboratory, unpublished data, no date). No data on the acute toxicity of these resins were located during the literature search.

6.4 - Cured Epoxy Resins

The finishing or hardening process renders the resin essentially inert; however, resins cured at room temperature may not completely harden for several days and can be a further source of exposure for skin sensitization (Lee and Neville, 1957; Fisch et al., 1969; May and Tanaka, 1973; Fregert et al., 1979; Fregert, 1981). Generally, though, the potential for dermatitis decreases as the resin progresses to full or complete cure.

Respiratory tract symptoms may occur as a result of inhalation of cured epoxy dusts during grinding and finishing of reinforced plastics products, as noted in the reports documented in Appendix Vb. In these cases the curing agents in the resin dusts appear to cause the symptoms.

6.5 - Curing Agents

The acute health effects associated with the use of some curing agents include eye irritation (Hosein, 1980), skin irritation (Berger et al., 1980), and respiratory tract symptoms (e.g., mild nasal irritations, asthma attacks) (Fawcett et al., 1977; Schlueter et al., 1978; Brubaker et al., 1979; Hosein, 1980; Ward and Davies, 1982). These effects may be due to inhalation of the vapours of the volatile compounds, to inhalation of epoxy resin powder dusts containing a curing agent, or in the case of skin irritation, to contact with the curing agent.

One of the aromatic amines used as a curing agent in epoxy resins, 4,4'-methylenedianiline is a suspected carcinogen based on animal studies (Steinhoff and Grundmann, 1970). This substance has also produced cases of occupational hepatitis and poisoning (see Section 6.5.1). Another aromatic amine, 4,4'-diaminodiphenyl sulfone, is an experimental tumorigen (Sax, 1979). However, limited research has been done on these substances so much of the evidence is considered inconclusive. Another commonly used aromatic amine curing agent known as m-phenylenediamine is considered to be noncarcinogenic (Holland et al., 1979; Berger, 1980; Wellington, 1983).

Appendix Ve provides a summary of the toxicity data for some of the curing agents commonly used in Ontario (where data are available). A general discussion on the toxicity of polyamines, anhydrides and polyamides follows. No reports were found in the literature of carcinogenicity or teratogenicity as a result of occupational exposure to curing agents used with epoxy resins.

6.5.1 - Polyamines

Polyamines can cause skin and eye irritation as well as respiratory tract symptoms (Hosein, 1980). Bourne et al. (1959) reported that exposure to vapours of volatile amines may produce eye irritation with lacrimation, conjunctivitis, and corneal edema resulting in "halos" around lights. After exposure to some polyamines, asthmatic symptoms have been observed and tentatively attributed to respiratory tract sensitization (Dernehl, 1951).

Aromatic amines used as curing agents are usually in solid form and are considered less irritating than some polyamines (Hosein, 1980). However, an incident of exposure to the curing agent 4,4'-methylene dianiline (MDA) in powder form resulted in an outbreak of toxic hepatitis in 13 mill workers (McGill and Motto, 1974). Also, 11 cases of toxic hepatocellular jaundice were reported between 1967 and 1976 by the Ontario Ministry of Labour in workers blending or bagging epoxy resins containing MDA (Dunn and Guirguis, 1979). Further, a study by Williams et al. (1974) described six cases of hepatitis among 300 workers who used epoxy resins containing MDA.

6.5.2 - Anhydrides

Anhydrides are capable of causing severe eye and skin irritation, and burns depending on the severity of contact (Dow, 1981). Some are irritants to the respiratory tract and may cause an allergic asthmatic response or lung injury (Fawcett et al., 1977; Rice et al., 1977; Schlueter et al., 1978; Herbert and Orford, 1979; Ward and Davies, 1982). Appendix Vb summarizes the effects (primarily respiratory) resulting from occupational exposure to epoxy resins containing various anhydrides.

6.5.3 - Polyamides

Polyamides are considered less hazardous to handle than the amines but can be moderately irritating to the skin and extremely irritating to the eyes (Hosein, 1980).

6.6 - Diluents

Diluents can be an important factor in the overall toxicity of epoxy resins and may represent a significant portion of the resin (e.g., 10 to 15 percent [Mathias, 1981]). Two of the most common diluents--glycidyl ethers and solvents--are discussed below.

6.6.1 - Glycidyl Ethers

Most of the glycidyl ethers are liquids and the rest are solids. Dermal contact is the major route of exposure to glycidyl ethers; exposure through inhalation is of secondary importance since glycidyl ethers have relatively low vapour pressures (NIOSH, 1978b). Appendix Vf summarizes the available data on the effects of skin contact with glycidyl ethers on humans.

No reports of carcinogenic or teratogenic effects of glycidyl ethers on humans were found in the literature. However, these effects have been investigated in animals and some data suggest that di(2,3-epoxypropyl) ether (DGE) should be regarded as a potential human carcinogen (NIOSH, 1978b). Animal experiments also indicate that DGE is a severe irritant to the skin (Sax, 1979). However, based on discussions with Dow Chemical (1984c), it is doubtful that DGE is used as a diluent with epoxy resins in Ontario. Other data suggest that n-butyl glycidyl ether (BGE) can cause genetic damage in human cells (Frost and Legator,

1982) and may cause an increase in fetal death rates in mice (Whorton et al., 1983). At the time of this Ontario survey BGE was still being used as a diluent in some epoxy resins. Some glycidyl ethers may also produce eye and respiratory tract irritation, skin sensitization, testicular abnormalities, alteration of leukocyte count, atrophy of lymphoid tissue and bone marrow cytotoxicity (NIOSH, 1978b; NIOSH, 1978c).

6.6.2 - Solvents

Toxicity data for solvents commonly used with epoxy resins in Ontario are summarized in Appendix Vg. Generally, occupational exposure to solvents used with epoxy resins may cause skin and eye irritation, and possibly defatting of the skin leading to dryness. Some solvents may also cause central nervous system depression and respiratory tract symptoms if the vapours are inhaled in high concentrations.

6.7 - Fillers and Pigments

Fillers used in epoxy resin formulations may present a serious hazard from inhalation when workers are exposed to the dusts, especially those from glass, silica, asbestos and powdered metals. While no health effects data on individual pigments were obtained for this study, Gleason et al. (1969) provide details on the toxic effects of many pigments used in commercial preparations.

6.8 - Ontario Workers at Risk by Industry Sector and Occupational Category

Claims reported to the Workers' Compensation Board indicate that risks to Ontario workers are primarily related to

contact dermatitis resulting from exposure to epoxy and phenolic resins. There have also been a number of claims involving vapour inhalation from plastics processes (excluding polyvinyl chloride), although the cause of vapour inhalation was not specified. A summary of the allowed claims relating to contact dermatitis and vapour inhalation are presented in Table 6.1 for the years 1976 to 1982. Claims associated with contact dermatitis include cases where the type of resin was not specified. In 1982, 24 of the 35 claims mentioned epoxy resins while in 1981, 50 of the 70 claims specified epoxy resins. Over the 7-yr period there does not appear to be a noticeable trend toward reduced exposures.

TABLE 6.1

ONTARIO WORKERS' COMPENSATION BOARD
ALLOWED CLAIMS RELATING TO
CONTACT DERMATITIS FROM RESINS AND
FUME INHALATION FROM PLASTIC PROCESSES

	Number of Claims	
Year	Contact Dermatitis Epoxy and Phenolic Resins	Fume Inhalation - Plastic Processes
1982	35	21
1981	70	30
1980	56	82
1979	75	36
1978	32	53
1977	55	14
1976	76	23

7 - MONITORING METHODS FOR EPOXY RESIN CHEMICALS AND DUSTS

7 - MONITORING METHODS FOR EPOXY RESIN CHEMICALS AND DUSTS

NIOSH has established air monitoring methods for epichlorohydrin, bisphenol A, diglycidyl ether of bisphenol A, and some aliphatic amines. Complete details of the monitoring and analytical techniques for these substances are contained in Appendix VI. In addition, there are NIOSH air monitoring methods for a number of glycidyl ethers. Brief documentation on the basic techniques is outlined below for each compound.

It appears that as of January 1984 no NIOSH air monitoring methods are available for any of the other curing agents and diluents listed in Appendix III, except in the case of anhydrides and solvents, as outlined in Section 7.1.2 below.

7.1 - Air Monitoring Techniques

7.1.1 - Ontario Air Monitoring Practices

Based on the Ontario industry survey, air monitoring of substances associated with epoxy resins appears to be limited to bisphenol A and epoxy resin powder dusts (see Table 5.2, page 42). Samples are generally taken using a filter collection device and are analyzed gravimetrically. Dow Chemical in Sarnia uses a standard gravimetric method rather than following other established procedures, as outlined in Section 7.1.2. One Ontario paint formulator advised that a mixed cellulose ester membrane filter was used for sampling solid DGEBA resin. Most formulators do not consider it necessary to monitor epoxy resin emissions since vapour pressures are so low and exposures are generally on an intermittent basis.

7.1.2 - NIOSH Air Monitoring Techiques

(a) Epichlorohydrin

For epichlorohydrin a 20-L sample of air is drawn through a charcoal tube at the rate of 0.2 L/min to trap the organic vapours present. The charcoal in the tube is then transferred to a small, stoppered sample container and the analyte is desorbed with carbon disulfide. An aliquot of the desorbed sample is subsequently analyzed by gas chromatography. This method was validated over the range of 11.7 to 43.1 mg/m^3 using a 20-L sample (NIOSH, 1977a).

(b) Bisphenol A and Diglycidyl Ether of Bisphenol A

A sample size of approximately 288 L is recommended at a flow rate of 1.6 L/min for bisphenol A and DGEBA. The sample is drawn through a glass fiber filter to collect the particulate; the exposed filter is then transferred to a screw cap vial and extracted with acetonitrile. The analysis is carried out using high pressure liquid chromatography (NIOSH, 1980).

While the NIOSH method mentioned above was established for particulate material, Dow Chemical in the Netherlands has recently developed a method to monitor phenol and Bisphenol A vapours (Oomens and Schuurhuis, 1983). Air samples are collected on commercial silica using the tube-pump method and subsequently analyzed by high performance liquid chromatography using ultraviolet detection at 275 nm. The method has been validated for a concentration range of 0.5 to 50 mg/m^3 (based on a 10-L sample) for both compounds.

(c) Polyamines

A general procedure for aliphatic amines in air is to sample at 200 mL/min for the desired time period (0.25 to 8 hours) using a tube containing silica gel. The silica gel is then transferred to glass-stoppered tubes and treated with sulfuric acid. A portion of the resulting acid solution is made alkaline with an excess of sodium hydroxide and the alkaline solution is then analyzed by gas chromatography with a flame ionization detector. The validated concentration range is 1 to 2,400 mg/m^3 in a 10-L sample of air (NIOSH, 1977b).

A separate NIOSH procedure is provided for diethylenetriamine (DETA) and ethylenediamine. For these two substances the sample is drawn through a tube containing silica gel and then stabilized by adding concentrated HCl. The adsorbed sections are then transferred to glass vials and treated with methanol solution. At this point an aliquot is alkalinized with sodium hydroxide, and benzaldehyde is added to form dibenzylidene derivatives. The solution is then analyzed by gas chromatography with flame ionization detection. The range of the method for ethylenediamine is 0.2 to 7 mg per sample; for diethylenetriamine it is 0.2 to 9 mg per sample (NIOSH, 1978).

No air monitoring procedures were found for any of the aromatic amines listed in Appendix III.

(d) Anhydrides

NIOSH air monitoring procedures are available for maleic anhydride, phthalic anhydride and trimellitic anhydride and brief details outlined

below have been summarized from the NIOSH Manual of Analytical Methods (1977 - 1980).

For maleic anhydride, the sample is collected in a midget bubbler and then hydrolyzed to maleic acid in the bubbler. Analysis is by high pressure liquid chromatography with an ultraviolet detector at 254 nm. The validated concentration range is 0.5 to 2.14 mg/m^3. For phthalic anhydride the sample is collected on a cellulose membrane filter and then treated with aqueous ammonia before being analyzed in a similar manner to maleic anhydride. The validated concentration range for phthalic anhydride is 5.5 to 28 mg/m^3.

Trimellitic anhydride is collected on a PVC-copolymer membrane filter and then extracted with methanol. Derivatization procedures are required to convert the anhydride to the trimethyl ester prior to analyzing with a gas chromatograph with flame ionization detector. The validated concentration range is 0.048 to 0.24 mg/m^3.

(e) Reactive Diluents (Glycidyl Ethers)

NIOSH air monitoring procedures are available for allyl glycidyl ether (AGE), n-butyl glycidyl ether (BGE), isopropyl glycidyl ether (IGE), and phenyl glycidyl ether (PGE). Validated concentration ranges are as follows.

Glycidyl Ether	Concentration Range (mg/m^3)
AGE	19 - 87
BGE	133 - 542
IGE	121 - 484
PGE	31 - 121

Generally, the glycidyl ethers are collected using a charcoal tube, desorbed with carbon disulfide, and then analyzed by gas chromatography. The exception is AGE which is collected in a Tenax-GC tube, desorbed with diethyl ether and then analyzed by gas chromatography (NIOSH, 1977 - 1980).

(f) Nonreactive Diluents (Solvents)

Air monitoring procedures are published by NIOSH for a number of solvents used in the epoxy resin industry. For many of the more common solvents used, e.g., toluene and xylenes, the procedure generally involves adsorption on charcoal, desorption with carbon disulfide, and analysis by gas chromatography. However, the NIOSH Manual of Analytical Methods (1977 - 1980) should be referenced for individual solvents.

7.2 - Medical Monitoring

The most common medical monitoring technique for epoxy resins is the patch test which involves applying a low concentration of a suspect substance to the body (usually the back) for a 48-h period. The methods most used worldwide, as recommended by the North American Contact Dermatitis Group (NACDG), are the closed Al patch test and the Finn chamber as described by Adams (1983). Only one respondent in the Ontario survey reported that patch-testing was part of the preemployment medical.

Suggested patch test concentrations for DGEBA resins, curing agents and diluents are shown in Table 7.1. Interpretation of results should be done the day after removal of the patch (i.e., 72 hours after application) using methods recommended by the International Contact Dermatitis Group (ICDG) (Adams, 1983).

TABLE 7.1

PATCH TEST CONCENTRATIONS FOR EPOXY RESINS AND SELECTED CURING AGENTS/DILUENTS
(Adams, 1983)

Substance	Patch Test Concentration in Petrolatum (percent)
DGEBA resin (low-molecular-weight resins)	1.0
Aliphatic Amines	
Diethylenetriamine (DETA)	0.5
Triethylenetetramine (TETA)	0.5
Tetraethylenepentamine (TEPA)	1.0
Diethylaminopropylamine (DEAPA)	1.0
Aromatic Amines	
4,4'-Methylenedianiline (MDA)	0.5
Reactive Diluents	
n-Butyl glycidyl ether (BGE)	0.25
Phenyl glycidyl ether (PGE)	0.25
Allyl glycidyl ether (AGE)	0.25

An alternative to the *in vivo* patch test which may provide more accuracy is an *in vitro* test for contact sensitivity using leukocytes as used by researchers in Japan (Nakano et al., 1981). The latter test involves use of guinea pig leukocytes as indicator cells. It was found that epoxy resins inhibit leukocyte migration activity and that the guinea pig assay correlates well with contact sensitivity in human volunteers.

The only other medical monitoring technique located in the literature involved a column extractive method used in Italy to determine aromatic amines in urine (Columbi et al., 1981). A discussion of the monitoring techniques for solvents used with epoxy resins was beyond the scope of this study.

The Ontario survey of the epoxy resin industry indicates that preplacement medicals are generally given to employees, although not specifically in relation to working with epoxy resins. Items commonly included in preplacement medicals are pulmonary function tests, medical history, work history, blood analysis and urinalysis. Other items occasionally included are ECG, liver function studies, vision and hearing tests. A summary of responses from Ontario industry on medical monitoring practices is contained in Table 7.2. Thirty-eight companies were surveyed but only 19 answered the question on preplacement medicals. Fifteen companies indicated that preplacement medicals were given and 9 out of these 15 provided pulmonary function tests. Respondents indicated that the total annual cost for periodic medical examinations ranged between $50 to $140/employee with an additional $21 to $135/employee for maintaining medical records on an annual basis.

TABLE 7.2

SUMMARY OF RESPONSES OBTAINED DURING ONTARIO INDUSTRY SURVEY OF MEDICAL MONITORING PRACTICES

Item	Number of Responses Received			
	Yes	No	Unknown*	Total
Pre-employment medicals given	15	4	0	19
Items included in pre-employment medical				
- pulmonary function test	9	5	1	15
- work history	11	3	1	15
- medical history	14	0	1	15
- blood analysis	11	3	1	15
- urinalysis	12	2	1	15
- patch testing	1	13	1	15
- chest x-rays	4	10	1	15
- liver function	1	13	1	15
- ECG	1	13	1	15
Periodic medical examinations given	7	12	0	19
Items included in periodic medical examinations				
- chest x-rays	5	2	0	7
- blood analysis	4	3	0	7
- urinalysis	3	4	0	7
- ECG	1	6	0	7
- pulmonary function	3	4	0	7
- liver function	1	6	0	7

*Respondent did not know answer.

8 - EXPOSURE CONTROLS

8 - EXPOSURE CONTROLS

Since the primary hazard of epoxy resins is related to skin contact, exposure controls are generally directed toward the use of protective equipment. However, the volatile vapours of diluents, as well as the dusts associated with bisphenol A, fillers, epoxy resin powders, and powdered curing agents require particular attention to adequate ventilation and possibly respiratory protection. The subsections below describe the types of protective equipment, engineering controls and administrative controls available for epoxy resins. Also included is a brief discussion on the use of substitutes as an alternative control measure.

8.1 - Engineering Controls

A summary of Ontario responses with regard to engineering controls is provided in Table 8.1. Only 9 out of 19 companies completing questionnaires answered the question regarding engineering controls; the completeness of the answers is questionable since it is believed, for example, that enclosed kettles are in more common use than is indicated in the table.

Those controls installed by Dow Chemical for the production of solid epoxy resins include a dust collector at the epoxy bagging machine at a capital cost of $10,000 (1983) and annual operating expenses of $500. In addition, a ventilation system installed above Dow's flaker cost $3,000 with annual operating expenses of $500. Both controls have an estimated life expectancy of 10 years.

8.1.1 - Containment

The primary control method used for the formulation of epoxy-based coatings is a closed process system,

TABLE 8.1

ENGINEERING CONTROLS IN PLACE
FOR EPOXY RESINS IN 1983
BASED ON ONTARIO SURVEY RESULTS

Respondent Identification	Industry Type	Engineering Controls						
		Fume Hoods	Local Exhaust Ventilation	General Exhaust Ventilation	Enclosed Kettles	Scrubbers	Dust Collectors	No Controls
A	Solid epoxy flakes			X	X	X	X	
B	Coatings			X	X			
C	"		X					
D	"							X
E	Adhesives		X	X				
F	"	X		X		X		
G	Electrical applications	X	X					
H	"	X	X	X		X		
I	"		X		X			

X = Company reported use of engineering control.

specifically a chemical reactor (for epoxy esters) or a closed container for epoxy resin coatings.

On some occasions during plant visits to coatings formulators, it was observed that the cover was not always on the mixing container and this is necessary to minimize solvent and/or curing agent vapours.

In the case of adhesives, a cover was observed on the containers during the mixing process but not during packaging operations. Although curing agent vapours may not be a serious concern in the packaging area since the workers are a few metres away from the containers, potential exposures will be minimized if a cover is placed over each container.

8.1.2 - Ventilation and Dust Collectors

Outlined below are general observations made at coatings, adhesives and reinforced plastics plants visited.

(a) Coatings

At the ball and pebble mills where resin, dry pigment and solvent are rotated in a grinding process, an elephant trunk extractor was operating in the milling area of one plant to collect dusts during dumping of materials. However, in another plant, only general ventilation was available in this area.

The coatings mixture is gravity fed from the grinding mills to large mixing vessels where general ventilation and local exhaust fans were in place at both plants to vent solvent emissions away from the working area.

In the drumming area there was an air exchanger in one plant but no local exhaust fans in either of the two plants visited. Workers in the drumming area do not find it necessary to wear any type of face mask (only rubber gloves).

For a discussion of engineering controls in other coatings processes using epoxy resins, see Section 2.4.2.

(b) Adhesives

In the adhesives plant visited, there was an open door to the outside environment in the area where the mixing of epoxy paste is carried out. Also, an elephant trunk air extractor was operating whenever the worker opened the mixing container to add filler.

Apart from general ventilation in the packaging area, there were no special engineering controls in place (e.g., local exhaust fans).

(c) Reinforced Plastics

In a plant where laminating of epoxy resin pipe is carried out, ceiling air fans and open doors comprised the general ventilation, with no local exhaust fans in place. In another Ontario plant where epoxy resin scuff liners are made for the interiors of tractor trailers, dilution ventilation is present.

Epoxy adhesives were observed being formulated and used in the reinforced plastics plant visited. Where the adhesives were being formulated, an elephant trunk air extractor was operating over the container where mixing of resin and filler was taking place, to draw filler dusts away from the worker's breathing zone.

During the use of epoxy adhesive to seal pipe flanges, it was observed that no local ventilation was provided and it was questionable whether it was necessary since there were no noticeable vapours and very small batch quantities (0.5 kg) were made up at any one time due to the limited pot life of the system used.

8.1.3 - New Technology

Accidental skin contact frequently occurs during the mixing of the resin and hardener. A number of recent technological innovations are likely to minimize this problem. Premixed frozen combinations of resin and curing agent which react upon being warmed to room air temperature is one such system (Mathias, 1981). This type of resin is used in Ontario by the electronics and aerospace industries (Fernandez, 1984). Another innovation is a small, hand-held packaging system which consists of a dual compartment bag with a seal separating the resin from the curing agent. This packaging system is commonly used in resin injection guns. When the seal is broken by pressure, the two components can be mixed by kneading without skin contact (Lawrence et al., 1974). The latter is commonly used in Ontario by small end users in construction applications.

8.2 - Protective Equipment

A summary of protective equipment available for workers in the Ontario epoxy resin industry in 1983 is provided in Table 8.2. When asked whether use of the equipment was optional or mandatory, respondents' answers varied considerably due to either the processes involved or general company policy. Section 5 details some specific processes where respirators are used.

TABLE 8.2

PROTECTIVE EQUIPMENT AVAILABLE
FOR WORKERS IN THE ONTARIO
EPOXY RESIN INDUSTRY IN 1983
(Based on Survey Results)

Industry Type	Respondent Identification	Overalls	Gloves	Aprons	Safety Goggles	Face Shields	Respirators	Eye Wash Stations and/or Showers	Barrier Creams
Coatings	A	X	X	X	X	X	X*	X	
"	B	X	X					X	
"	C	X	X	X	X		X***	X	
"	D	X	X		X		X***	X	
"	E	X	X	X	X	X	X*	X	X
"	F	X	X	X	X	X	X**	X	
"	G	X	X		X	X	X***	X	X
"	H	X	X		X		X*	X	
Adhesives	I	X	X			X			
"	J	X	X	X	X	X		X	
Electrical/ communications	K	X	X	X	X	X	X**	X	X
"	L		X	X	X		X***	X	
"	M	X	X	X	X			X	
Automotive	N	X	X	X	X	X	X**	X	
"	O	X	X	X	X	X	X*	X	
Construction	P	X	X			X			
Reinforced plastics	Q	X	X	X	X	X	X**		
" "	R	X	X	X	X	X	X†	X	
Other (Dow Chemical)	S	X	X		X		X*	X	

* Organic vapour cartridge and dust filter masks.
** Respirator type not identified.
***Organic vapour cartridge only.
† Dust filter masks only.

Protection and care of the skin is essential to protect those working with epoxy resins. All exposed parts of the body should be protected from contamination when epoxy resins or compounds containing epoxy resins are used. Any component is liable to cause irritation of the exposed skin. Rubber or polyethylene gloves, long protective sleeves, eye goggles, rubber aprons and disposable smocks or coveralls should be available for the workers' protection. Overalls should always be removed when workers go to the canteen or home and should be changed at least weekly (Ehrner-Samuel and Sjoholm, 1976). In addition, high buttoned collars will protect the workers' necks and chests. When there is a danger of splashing, droplets, mist or dust contamination, full face shields may be necessary in some applications to protect the face, eyes and respiratory tract (Lemon, 1972).

Protective rubber or plastic gloves provide some protection but epoxy resins are known to penetrate these materials and cause dermatitis in some sensitized individuals (Mathias, 1981). Disposable rubber or plastic gloves changed frequently may reduce the potential for penetration by the resin. Gloves should be changed twice daily or more frequently if worn by a sensitized individual, and the use of white cotton liners is recommended (Firmingham, 1969; Gunter and Lucas, 1974).

There is some controversy as to the usefulness of barrier creams. Although they do afford some protection, they may create a false sense of security (Gunter and Lucas, 1974).

Easily accessible cleanup stations with moisturizing creams and soaps should be available in areas using epoxy resins. Since it takes several hours of contamination to elicit a dermal reaction, prompt removal of skin contamination will enable persons, even with known sensitivity, to continue to work with epoxies (Gunter and Lucas, 1974). The use of sulfonated oil soap or other neutral soaps is preferable to harsh or abrasive granulated hand cleaners (Firmingham, 1969) and because cleaners and repeated hand washing tend to defat

the skin, refatting creams should also be used (Lemon, 1972). The use of solvents for cleaning the skin is dangerous because they defat the skin and allow chemicals to penetrate more easily. Cloth towels should never be used. Skin complaints are almost unknown in plants where paper towels are used (Ehrner-Samuel and Sjoholm, 1976).

Observations made during the Ontario plant survey indicated that dust masks are worn by some workers but not by others when dumping solid resin flakes, dry pigment or filler. Also, gloves are not worn by all workers and no organic vapour respirators were observed in use. Comments received during the survey indicated that soap and water were commonly used to remove resin from workers' skin, but solvents were also used in some cases.

8.3 - Administrative Controls

A summary of the administrative controls in place for epoxy resins in 1983 is provided in Table 8.3.

One of the key administrative practices is preplacement medical examinations so that persons with a history of skin problems such as excessive dryness, acne or allergies can be discouraged from working in this type of occupational environment. Also, where powdered products are used, workers (especially those with a preexisting history of respiratory problems) should be made aware of the potential respiratory hazards of working with these substances.

Another area requiring attention is in the handling of epoxy resins. Due to the nature of epoxy resins, there is a tendency for workers to handle them carelessly. They physically resemble a number of well known innocuous materials such as corn syrup or vegetable oils and the effect on the skin is not immediate, therefore providing no incentive for an operator to decontaminate himself promptly. Workers can use epoxies for years before sensitization becomes

TABLE 8.3

ADMINISTRATIVE CONTROLS IN PLACE FOR EPOXY RESINS IN 1983 BASED ON ONTARIO SURVEY RESULTS*

Industry Type	Respondent Identification	Preplacement Medicals	Worker Rotation	Transfer of Sensitized Workers	Limitation of Production Time
Coatings	A	X			
"	B	X			
"	C	X			
"	D	X			
"	E				
"	F	X	X		
"	G	X			
"	H	X		X	
"	I	X		X	X
Adhesives	J	X			
"	K	X	X	X	
"	L				
Electrical/ communications	M	X		X	
"	N	X		X	
"	O				
"	P	X	X	X	
Automotive	Q	X			
Reinforced plastics	R				
Other (Dow Chemicals)	S	X		X	

X = Respondents with administrative controls in place.

apparent, with no real change in work practice. Also, epoxy resins are extremely sticky and can be transferred easily by casual contact, even outside the areas of their immediate use (Purdew, 1980). For these reasons, worker education and rigidly supervised hygieric control of the workplace are important.

Special care is required during the handling of epoxy resins by construction workers. Unfamiliarity with the use of chemicals in daily work may cause construction workers to be at greater risk than their other industrial counterparts. Washing facilities and designated waste disposal sites often may be absent or distant, particularly where smaller companies are concerned. Therefore, it is important that personnel who handle these products are properly instructed as to the possible hazards and handling techniques.

Labeling of product hazards is particularly important and it may be desirable to provide multilingual instructions to ensure that all workers, e.g., operators, storemen, janitors, etc, clearly understand any hazards that may be associated with handling the product. Where cans and drums of epoxy resin were observed, a skin hazard notation was present on the label.

The survey of Ontario formulators and users of epoxy resins indicated a broad variation in the degree of worker education specific to epoxy resins. Five companies had some special instruction, varying from occasional films or lectures to training sessions identifying health effects and handling methods. Three companies had industrial hygiene programs which provided workers with a hazard rating for chemicals, including epoxy resins, to which they are exposed. Fourteen companies used safety data sheets and/or on-the-job instruction and ten companies provided no instruction at all. Samples of material safety data sheets provided for epoxy resins sold in Ontario by Ciba-Geigy, Dow, and Shell are contained in Appendix VII.

8.4 - Use of Substitutes

Where substitution is considered as a form of exposure control, there are three possibilities

- substitution of a different resin
- substitution with a higher molecular weight resin for one of lower molecular weight
- substitution of a different curing agent.

These alternatives are discussed individually below; much of the material in this section is based on comments made by Adams (1977) in his paper "Allergen Replacement in Industry". None of the formulators questioned indicated they were considering substitutions at the present time.

8.4.1 - Substitution of a Different Resin

Due to the excellent adhesive, mechanical and electrical insulating properties of epoxy resins and their high chemical stability, it is very difficult and often impossible to find an appropriate substitute with similar properties. This is especially apparent when considering the economic factor, since epoxies tend to be more costly than other plastics and would, therefore, be replaced if cheaper, acceptable alternatives were available. However, there are some applications such as in laminating and adhesives where polyester or phenolic resins can be substituted if strength is not a requirement (Adams, 1977), although the adhesion of epoxy resins is generally considered superior (May and Tanaka, 1973). Also, one should be cautious that substitution of an epoxy resin with another resin does not add to potential worker hazard. Substitutes such as urethanes are considered by at least one formulator

to be more hazardous than epoxy resins except for dermatitis problems, which are relatively easily controlled.

8.4.2 - Substitution of a Higher Molecular Weight Resin for One of Lower Molecular Weight

Substitution of a higher molecular weight resin for one of lower molecular weight may avoid a skin reaction since liquid resins generally have a greater sensitizing potential than solid resins having higher molecular weights. However, this type of substitution may not always be possible, depending on the application.

8.4.3 - Substitution of a Different Curing Agent, Catalyst or Diluent

It is this area which probably allows most flexibility with epoxy resins. There are a large number of curing agents, catalysts and diluents available and it is likely that an alternative could be found for many applications if necessary. For example, in Sweden, low-molecular-weight aliphatic amines such as diethylenetriamine and triethylenetetramine are considered particularly hazardous so are avoided where possible (Ehrner-Samuel and Sjoholm, 1976). Generally amine-terminated polyamides (Versamids), amine adducts, and other modified amines are considerably less irritating than the simpler aliphatic amines (Ingberman et al., 1957; Mathias, 1981).

8.5 - Economic Impact of Controls

The economic impact of controls is difficult to determine since the range of options available for a control strategy associated with epoxy resins is considerable.

For example, if epichlorohydrin were regulated at the current ACGIH guideline level of 2 ppm, it is doubtful that there would be any impact on the Ontario epoxy resin industry. However, this would need to be confirmed by air monitoring of epichlorohydrin, particularly in the formulating sector. Also, other Ontario industries may be adversely affected if epichlorohydrin were regulated since it may be used in a number of other applications outside the epoxy resin industry (e.g., as a solvent or in the rubber and paper industries).

Very limited research has been carried out on bisphenol A and therefore, it would be difficult to justify a regulation for this substance. If regulations were instituted to control the dusts and/or vapours of bisphenol A, curing agents, diluents, solvents or cured epoxy resins, it is likely that this would have an economic impact due to the industrial hygiene activities which would need to be implemented, e.g., air monitoring. A further economic impact would be felt if engineering controls and additional protective equipment were required to achieve the regulated level. Since very little monitoring of the various epoxy resin constituents has been done by Ontario industry and levels in the work environment are unknown, the extent of the economic impact is unknown.

Discussion with some Ontario formulators and users of epoxy resins indicates that open containers are used for mixing of small batches. In one case, the plant manager advised that local ventilation was not provided over the open drums and kettles. Also, dust levels associated with epoxy resins may be excessive in some cases. Therefore, at least some Ontario companies formulating or using epoxy resins would be affected economically if they were forced to provide local ventilation in the plant area affected. One survey respondent indicated that "major costs would be incurred if substitutes were required", although presumably this would be dependent on the nature and extent of use by each industry sector.

8.6 - Worker Attitude to Controls

The following labour organizations were invited to submit their concerns regarding worker exposure to epoxy resins and curing agents:

- Chemical Energy and Allied Workers Division, Canadian Conference of Teamsters
- Communications Workers of Canada
- Energy and Chemical Workers Union
- International Woodworkers of America
- Ontario Federation of Labour
- United Auto Workers
- United Electrical, Radio and Machine Workers of America
- United Steel Workers of America.

A summary of comments received is contained in Table 8.4. Generally, no specific concerns were registered by any of the Ontario-based labour organizations with the exception of the Communications Workers of Canada. This latter group indicated that a DGEBA/novolac resin is no longer used to plug telephone cables due to mutagenic evidence based on the Ames test (Cwitco, 1984).

8.7 - Employer Attitude to Controls

Following are the results of the industry survey when asked what type of regulatory strategy should be introduced to control worker exposure to epoxy resins.

Option	Number of Respondents
A - Voluntary exposure limit	11
B - Mandatory exposure limit	3
C - Comprehensive standard with mandatory medical examination, record keeping, monitoring and exposure limit requirements	1
D - Other	4
TOTAL	19

TABLE 8.4

SUMMARY OF LABOUR ORGANIZATION COMMENTS
REGARDING WORKER EXPOSURE TO EPOXY RESINS

Labour Organization	Contact	Comments
Chemical Energy and Allied Workers Division (Canadian Conference of Teamsters)	J. J. Phelan, Director	No concerns registered
Communications Workers of Canada	G. Cwitco, National Representative	One epoxy resin with trade name Ca-C was used to plug telephone cables but has since been banned by Labour Canada due to mutagenic evidence associated with this particular DGEBA/novolac mixture. Currently involved in discussion with an employer and University of Toronto to determine if an epidemiological study involving those exposed to Ca-C is possible.
Energy and Chemical Workers Union	D. Ublansky, Legislative and Health Coordinator	No specific concerns registered with National Office as of January 27, 1984.
International Woodworkers of America	J. M. Bedard, President	No concerns registered
Ontario Federation of Labour	C. Pilkey, President	No concerns registered
United Auto Workers	J. Gill Health and Safety Coordinator	No concerns registered. Suggested we contact individual locals.

Table 8.4
Summary of Labour Organization Comments
Regarding Worker Exposure to Epoxy Resins - 2

Labour Organization	Contact	Comments
United Electrical, Radio and Machine Workers of America	J. Turk Health and Safety Coordinator	No concerns registered
United Steel Workers of America	D. Patterson, Director, District 6	No specific concerns registered. Suggested we contact Communications Workers of Canada who have had some complaints from workers regarding epoxy resins.
	C. Gillett Occupational Health and Safety Coordinator, District 6	

Two out of three preferring a mandatory exposure limit indicated that any government control strategy should be specific to components of the system that are hazardous. Those in the "other" category (D above) generally did not feel that government controls were necessary for epoxy resins.

Two formulators commented that there are many other materials that deserve higher priority for investigation than epoxies. Another comment indicated that any legislation pertaining to epoxy resins would be difficult to enforce in light of the large number of users and variety of applications.

8.8 - Trade Association Concerns

Comments received by trade associations are summarized in Table 8.5. The Canadian Paint and Coatings Association and the Society of the Plastics Industry of Canada were the only associations submitting a formal response to the survey.

TABLE 8.5

SUMMARY OF TRADE ASSOCIATION COMMENTS
REGARDING WORKER EXPOSURE TO EPOXY RESINS

Trade Organization	Contact	Date of Response	Comments
Adhesives and Sealants Manufacturers Association of Canada	J. A. Teeter, Secretary-Treasurer	Jan 16/84	No combined industry response through the Association, although individual member companies participated in the industry survey.
Canadian Association of Metal Finishers	W. O. Burgoon, Chairman	Jan 4/84	Not aware of any concerns regarding epoxy resins by member companies; primary occupation of members is electroplating of metal finishes on metal.
Canadian Chemical Producers' Association	D. W. Goffin, Technical Advisor	Dec 8/83	Member companies were advised to respond individually; the only comments received were completed questionnaires by some member companies.
Canadian Manufacturers of Chemical Specialities Association	J. Chevalier, Executive Director	Jan 10/84	Member companies using epoxy resins have already been contacted in the industry survey; Association has nothing to add.
Canadian Paint and Coatings Association	R. W. Murry, Executive Vice-President	Jan 26/84	Provided data on epoxy resin use and worker exposure (Section 4.1 and Table 6.2) as well as a general mortality study on paint manufacturing industry.
Society of the Plastics Industry of Canada	B. R. Darrah, Assistant Technical Director	Feb 21/84	Provided SPI (US) response to EPA's recent health assessment of epichlorohydrin; SPI questions whether ECH should be considered a potential human carcinogen based on evidence to date (SPI, January 6, 1984).

9 - EXPOSURE LIMITS

9 - EXPOSURE LIMITS

As of January 1984, no occupational exposure limits exist for epoxy resins (cured or uncured). However, some exposure limits and guidelines do exist for individual components of the resin. Appendixes VIIIa and VIIIb list exposure limits for epichlorohydrin, bisphenol A, and some common curing agents (DETA, MDA, and phthalic anhydride) used with epoxy resins in Ontario. Exposure limits are not available for most other curing agents except for ethylene diamine and some anhydrides (i.e., maleic anhydride and trimellitic anhydride) which were not identified as being used with epoxy resins in Ontario.

Exposure limits also exist for five glycidyl ethers (AGE, BGE, DGE, IGE and PGE) as shown in Appendixes VIIIc and VIIId. The range in values between the various glycidyl ethers indicates a significant difference in degree of hazard perceived by the various agencies, depending on the glycidyl ether. Due to the scope of the study no attempt was made to document exposure criteria for the large number of solvents and fillers which may be used with epoxy resins.

9.1 - Canada

Generally, provincial exposure limits for epichlorohydrin, diethylenetriamine (DETA), 4,4'-methylenedianiline (MDA), phthalic anhydride and glycidyl ethers follow ACGIH guidelines with the exception of Alberta, British Columbia, Quebec and Saskatchewan who have developed their own regulations. The only province with an exposure limit for bisphenol A is British Columbia where the maximum concentration of 2.8 mg/m^3, allowed at any one time, is the same as for diglycidyl ether (DGE). This rationale is questionable since these two compounds differ considerably (physically and chemically). Limited research studies on bisphenol A suggest that it is primarily a skin hazard (Krajewska and Rudzki,

1976; Allen and Kaidbey, 1979; Boiano, 1981); conversely DGE is regarded as a potential occupational carcinogen (NIOSH, 1978b).

9.2 - United States

Exposure guidelines or limits have been established by NIOSH, OSHA and ACGIH for some substances associated with epoxy resins. Those of interest to the Ontario work environment are listed in Appendixes VIIIb and VIIId. The rationale for ACGIH guidelines and NIOSH recommended standards is outlined in Appendix VIIIe.

9.3 - Other Countries

Data were compiled, where available, on exposure limits in other countries for substances associated with epoxy resins and these are presented in Appendixes VIIIb and VIIId. Information on the rationale for assigning limits was requested from appropriate regulatory agencies in Sweden, France, Norway, West Germany and Britain. Responses were received from Norway, Sweden and West Germany but no data on the rationale for assigning limits was included.

In the case of Denmark, the Labour Inspection Service has a regulation on epoxy products which requires registration of the products and their constituents, labeling, handling restrictions, spray application restrictions (e.g., not outside spray booths), personal hygiene provisions, a training course, and exclusion of persons with eczema or confirmed epoxy allergy (Jarvisalo et al., 1984).

10 - RECOMMENDATIONS FOR ACTION OR FURTHER STUDY

10 - RECOMMENDATIONS FOR ACTION OR FURTHER STUDY

With the exception of research that has been carried out on epichlorohydrin, DGEBA resins and glycidyl ethers, very little is known about many of the curing agents used or about other types of epoxy resins. As a result, the following areas are recommended for action or further study to assist in the development of a control strategy for epoxy resins.

- Sample a variety of epoxy resins for epichlorohydrin in a range of industries to confirm its absence in the Ontario workplace atmosphere or that it is within existing guidelines.

- Sample for other substances of concern in Ontario where established sampling methods are available (e.g., aliphatic amines, phthalic anhydride, glycidyl ethers and epoxy resin dusts).

- Validated sampling and analytical procedures are required for many of the substances used with epoxy resins before Ontario industries can effectively monitor workplace concentrations. Some of the substances identified as being used in Ontario for which there are no established sampling and analytical procedures published are as follows:

  - 4,4'-diaminodiphenylsulfone (DDS)
  - 4,4'-methylenedianiline (MDA)
  - hexahydrophthalic anhydride
  - nadic methyl anhydride
  - boron trifluoride monoethylamine (BF_3MEA)
  - dicyandiamide (Dicy)
  - 2,4,6-tris(dimethylaminomethyl)phenol (DMP-30)
  - benzyldimethylamine.

- More research appears to be warranted on the chronic health effects of exposure to epoxy resins in view of the contradictory evidence obtained in bacteria and animal tests with regard to mutagenicity and carcinogenicity. These investigations should involve careful characterization of the product to establish what, if any, types of resins or constituents of the resin produce a mutagenic, carcinogenic or tumorigenic potential and whether the addition of diluents such as some glycidyl ethers may increase this potential.

- Research is also required on the acute and chronic health effects of occupational exposure to many of the substances used as curing agents and catalysts for which there is little or no data at present. These substances include (but are not necessarily limited to) the following known to be used in Ontario:

  - aminoethylpiperazine
  - bisphenol A
  - diethylenetriamine (DETA)
  - polyglycoldiamine
  - triethylenetetramine (TETA)
  - 4,4'-diaminodiphenyl sulfone (DDS)
  - 4,4'-methylenedianiline (MDA)
  - dimethylaniline (DMA)
  - hexahydrophthalic anhydride
  - nadic methyl anhydride
  - dicyandiamide (Dicy)
  - benzyldimethylamine
  - boron trifluoride monoethylamine (BF_3MEA)
  - 2,4,6-tris(dimethylaminomethyl)phenol (DMP-30).

The paucity of data available on the above-mentioned substances does not, at present, allow a responsible assessment of hazard to be made for most of them. However, it may be prudent to consider introduction of an exposure guideline for bisphenol A dusts and epoxy dusts (cured and uncured) similar to other nuisance particulates until a safe level is proven or more data become available on potential hazards. A more restrictive level may be warranted for cured epoxy dusts and epoxy powder dusts containing curing agents in view of the possibility of respiratory problems occurring from inhalation of the curing agent component of the resin. Alternatively, a separate exposure guideline for a given curing agent component of epoxy resin dusts or vapours could be assigned where sufficient data on health effects are available.

Followup on recent reports (August 1984) relating to sensitizing products of thermally induced breakdown of epoxy resins should be undertaken with a view to identifying suitable remedial or problem avoidance measures.

APPENDIX I

ORGANIZATIONS CONTACTED DURING EPOXY RESIN STUDY

APPENDIX I

ORGANIZATIONS CONTACTED DURING
EPOXY RESIN STUDY

INDUSTRY

Almatex Limited
(Attention: Mr. T. J. Wolf
President)
P.O. Box 2274
Terminal A
London, Ontario

Arjem Building Preservations Limited
(Attention: Mr. R. Milburn)
P.O. Box 504
Brampton, Ontario
L6X 2L4

Borden Chemical
Division of the Borden Company, Limited
(Attention: Mr. T. Larson
President)
595 Coronation Drive
West Hill, Ontario
M1E 4R9

Canadian General Electric
(Attention: Mr. A. S. Cartwright
Chief Executive Officer)
Commerce Court North
25 King Street West
Toronto, Ontario
M5H 1B4

Ciba-Geigy Canada Ltd.
(Attention: Mr. H. B. Knuchel
President)
6860 Century Avenue
Mississauga, Ontario
L5N 2W5

C.I.L. House
(Attention: Mr. C. H. Hantho
President & Chief Executive Officer)
P.O. Box 200
Station A
Willowdale, Ontario
M2N 6H2

Devcon Canada Limited
(Attention: Mr. R. Bertrand
General Manager)
22 Golden Gate Court
Scarborough, Ontario
M1P 3A5

Dow Chemical Canada Inc.
(Attention: Mr. J. D. Hembree
President)
Modeland Road
P.O. Box 1012
Sarnia, Ontario
N7T 7K7

Ford Motor Co. of Canada Ltd.
Oakville, Ontario

The Foundation Group of Companies
Foundation Engineering and Construction
(Attention: Mr. John Otter
Vice-President, Engineering)
1 Yonge Street
Toronto, Ontario
M5E 1E8

Garret Manufacturing Limited
240 Atwell Drive
Rexdale, Ontario

General Motors of Canada Ltd.
Oshawa, Ontario

George Wimpey Canada Ltd.
(Attention: Mr. John Tait)
80 North Queen Street
Etobicoke, Ontario
M8Z 2C9

Halliday Armstrong Limited
3260 Lenworth Drive
Mississauga, Ontario

Halltech Inc.
(Attention: Mr. W. Holt
President)
465 Coronation Drive
West Hill, Ontario
M1E 2K2

H.B. Fuller Canada Inc.
(Attention: Mr. D. McLeod
President)
880 Rangeview Road
Mississauga, Ontario
L5E 1G9

Hysol Canada Inc
(Attention: Mr. D. Hickson
General Manager)
345 Finchdene Square
Scarborough, Ontario
M1X 1B9

Industrial Adhesives, Division of Chromasco Ltd.
(Attention: Mr. D. L. Adams
President)
90 Tycos Drive
Toronto, Ontario
M6B 1W2

Inmont Canada Inc.
(Attention: Mr. J. G. McWade
President & General Manager)
P.O. Box 100
Brantford, Ontario
N3T 5M3

International Paints (Canada) Ltd.
(Attention: Mr. Van der Net
General Manager)
188 New Toronto Street
Toronto, Ontario
M8V 2E8

Lepage's Limited
(Attention: Mr. J. Keith Russell
President)
50 West Drive
Brampton, Ontario
L6T 2J4

MacNaughton-Brooks Limited
(Attention: Mr. M. P. MacNaughton, Chairman
Mr. J. S. Brooks, President)
3637 Weston Road
Weston, Ontario
M9L 1W1

McBride Group
(Attention: Mr. R. Polidoro
Manager, Epoxy Division)
18 Curity Street
Toronto, Ontario

Mobil Chemical Canada Ltd
Coatings Division
(Attention: Mr. R. G. Hoffman
Vice-President & General Manager)
645 Coronation Drive
West Hill, Ontario
M1E 4R6

Multi-Clean Canada
(Attention: Mr. R. Harland
President & General Manager)
410 Norfinch Drive
Downsview, Ontario
M3N 1Y5

Newcarl Company Limited
(Attention: Mr. G. Moreau
President)
215 Lakeshore Boulevard
Toronto, Ontario

Northern Telecom Canada Limited
304 The East Mall
Etobicoke, Ontario

Northern Yacht Limited
(Attention: Mr. D. Furnis)
395 Frankcom Street
Ajax, Ontario
L1S 1R4

Pigott Construction Limited
(Attention: Mr. D. W. Edgerley)
304 The East Mall
Etobicoke, Ontario
M9B 6E2

Polyply Limited
(Attention: Mr. J. Call)
184 Fairall Street
Ajax, Ontario
L1S 1R6

PPG Industries Canada Ltd.
(Attention: Mr. D. R. Pepall
President)
50 St. Clair Avenue West
Toronto, Ontario
M4V 1M9

Protective Plastics Ltd.
(Attention: Mr. P. Szasz
President)
P.O. Box 156
Milliken, Ontario
L0H 1K0

Reichhold Limited
(Attention: Mr. L. Hollander
President & Chief Operating Officer)
600 The East Mall
Islington, Ontario
M9B 4B1

Schenectady Chemicals Can. Ltd.
(Attention: Mr. R. Morris
General Manager)
319 Comstock Road
Scarborough, Ontario
M1L 2H3

Shell Canada Chemical Company
(Attention: Mr. L. F. Bolger
President)
P.O. Box 400
Terminal A
Toronto, Ontrio
M5W 1E1

Sterling Limited
(Attention: Mr. J. E. Hanson
President)
P.O. Box 554
St. Catharines, Ontario
L2R 6X1

Swift Adhesives Company
(Attention: Mr. T. Clayton
President)
383 Orenda Road
Bramalea, Ontario
L6T 1G4

3M Canada Inc.
(Attention: Mr. J. T. Myser
President)
P.O. Box 5757
London, Ontario
N6A 4T1

LABOR ORGANIZATIONS

Chemical Energy & Allied Workers Division
(Attention: Mr. J. Phelan
Canadian Director)
1262 Don Mills Road
Suite 48
Don Mills, Ontario
M3B 2W7

Energy & Chemical Workers Union
(Attention: Mr. K. V. Rogers
Ontario Coordinator)
603 Argus Road
Oakville, Ontario
L6J 6G6

International Woodworkers of America
(Attention: Mr. J. M. Bedard
President)
2088 Weston Road
Weston, Ontario
M9N 1X4

Ontario Federation of Labour
(Attention: Mr. C. Pilkey
President)
15 Gervais Drive
Don Mills, Ontario
M3C 1Y8

United Auto Workers
(Attention: Mr. J. Gill)
205 Placer Court
North York, Ontario
M2H 3H9

United Electrical Radio and
Machine Workers of America
(Attention: Mr. Richard Barry
President)
10 Codeco Court
Don Mills, Ontario
M3A 1A2

United Steel Workers of America
(Attention: Mr. D. Patterson)
100 Lombard Street, 4th Floor
Toronto, Ontario
M5C 1L4

TRADE ASSOCIATIONS

Adhesives and Sealant
Manufacturers of Canada
(Attention: Mr. John A. Teeter
Secretary-Treasurer)
156A King Street East
Toronto, Ontario
M5A 1J3

Canadian Association of Metal Finishers
(Attention: Mr. W. O. Burgoon
Chairman)
1232 Dillon Road
Burlington, Ontario
L7M 1N3

The Canadian Chemical Producers Association
(Attention: Mr. J. M. Belanger
President)
Suite 805
350 Sparks Street
Ottawa, Ontario
K1R 7S8

Canadian Manufacturers of Chemical
Specialties Association
(Attention: Mr. J. Chevalier
Executive Director)
116 Albert Street
Suite 710
Ottawa, Ontario
K1P 5G3

Canadian Paint and Coatings Association
(Attention: Mr. R. W. Murray
Executive Vice-President)
Suite 825
515 Ste. Catherine W.
Montreal, Quebec
H3B 1B4

Society of the Plastics Industry
of Canada
(Attention: Mr. B. Darrah)
1262 Don Mills Road
Don Mills, Ontario
M3B 2W7

APPENDIX II

CHEMICAL AND PHYSICAL PROPERTIES
OF SPECIFIC COMPOUNDS
ASSOCIATED WITH EPOXY RESINS IN ONTARIO

APPENDIX II

CHEMICAL AND PHYSICAL PROPERTIES OF SPECIFIC COMPOUNDS ASSOCIATED WITH EPOXY RESINS IN ONTARIO

Chemical Name or Group	Synonym	Formula	Appearance	Odor	Boiling Point (°C)	Flash Point (°C)	Density	Mol Wt	Ref
Epichlorohydrin	Chloro-methyloxirane	C_3H_5OCl	Colorless liquid	Chloro-form like	117.9	40.6(OC)*	1.1761 @ 20°/20°	92.52	Sax, 1979
2,2-bis(4-hydroxyphenyl) propane	Bisphenol A	$C_{15}H_{16}O_2$	White flakes	Phenolic				228	Sax, 1979
Aliphatic Amines									
- Triethylenetetramine	TETA	$C_7H_{20}N_4$	Yellowish liquid		278.0	135.0	0.982	146.24	Sax, 1979
- Diethylenetriamine	DETA	$(NH_2C_2H_4)NH$	Yellowish liquid	Ammonia-like	207.0	101.7	0.9586	103.17	Sax, 1979
- Aminoethylpiperazine		$H_2NCH_2CH_2N(CH_2)_4NH$	Light colored liquid		220.4	93.3(OC)*	0.9852 @ 20°/20°	129.2	Sax, 1979
- Polyglycoldiamine		$HO(C_2H_4O)_2C_3H_5(NH_2)(NH_2)$							Napier, 1983
Aromatic Amines									
- 4,4'-Diaminodiphenyl sulfone	DDS	$C_{12}H_{12}O_2N_2S$	Crystals					248.3	Sax, 1979
- 4,4'-Methylenedianiline	MDA	$C_6H_5NHCH_2NHC_6H_5$			232.0				Napier, 1983
- Dimethylaniline	DMA	$C_6H_5N(CH_3)_2$	Liquid		193.1	62.8(CC)*	0.9557 @20°/4°	121.18	Sax, 1979

*OC - open cup
CC - closed cup

Appendix II
Chemical and Physical Properties of Specific Compounds
Associated with Epoxy Resins in Ontario - 2

Chemical Name or Group	Synonym	Formula	Appearance	Odor	Boiling Point (°C)	Flash Point (°C)	Density	Mol Wt	Ref
Acid Anhydrides									
- Phthalic anhydride	Phthalandione	$C_8H_4(CO)_2O$	White crystalline needles		295.0	151.7(CC)*	1.527 @ 4°	148.11	Sax, 1979
- Nadic methyl anhydride	NMA	$C_{10}H_{10}O_3$							Lee and Neville, 1967
- Hexahydrophthalic anhydride	HHPA	$C_8H_{10}O_3$	Clear liquid or glassy solid		158 @ 17 mm			154.1	Sax, 1979
Other Curing Agents									
- Dicyandiamide		$H_2NC(NH)NHCN$	White crystals				1.400 @ 25°	84.1	Sax, 1979
- Boron trifluoride-monoethylamine		$C_2H_7NBF_3$						122.9	Sax, 1979
- 2,4,6-Tris(dimethylaminomethyl)phenol	DMP-30	$C_6H_2OH(CH_2NH[CH_3]_2)_3$							Napier, 1983
- benzyldimethylamine		$C_6H_5CH_2N(CH_3)_2$							Napier, 1983
Diluents/Solvents									
- Alkyl glycidyl ether		$C_{15}H_{30}O$-$C_{17}H_{34}O$							Dow Chemical
- n-Butyl glycidyl ether	BGE	$C_7H_{14}O_2$						130.1	Sax, 1979

*CC - closed cup

Appendix II
Chemical and Physical Properties of Specific Compounds
Associated with Epoxy Resins in Ontario - 3

Chemical Name or Group	Synonym	Formula	Appearance	Odor	Boiling Point (°C)	Flash Point (°C)	Density	Mol Wt	Ref
Diluents/Solvents (cont)									
- Acetone		CH_3COCH_3	Colorless liquid	Mint-like	56.48	-17.8(CC)*	0.7972 @ 15°	58.08	Sax, 1979
- "Cellosolve"	Ethylene glycol Monoethyl ether	$C_4H_{10}O_2$	Colorless liquid	Practically odorless	135.1	94.4 (CC)*	0.9360	90.12	Sax, 1979
- Glycol alcohol	Ethylene glycol	CH_2OHCH_2OH	Colorless liquid		197.5	111.1(CC)*	1.113 @ 25°/25°	62.1	Sax, 1979
- Methyl ethyl ketone	Butanone	$CH_3COCH_2CH_3$	Colorless liquid	Acetone-like	79.57	-5.6(TOC)*	0.8061 @ 20°/20°	72.10	Sax, 1979
- Methyl isobutyl ketone	4-methyl-2-pentanone	$(CH_3)_2CHCH_2COCH_3$	Clear liquid		118.0	22.8	0.803	100.1	Sax, 1979
- Methylene chloride	Dichloromethane	CH_2Cl_2	Colorless liquid		39.8		1.326 @ 20°/20°/4°	84.94	Sax, 1979
- 1,1,1-Trichloroethane	Methyl-chloroform	CH_3CCl_3	Colorless liquid		74.1	none	1.3492 @ 20°/4°	133.42	Sax, 1979
- Toluene	Toluol	$C_6H_5CH_3$	Colorless liquid	Benzene-like	110.4	4.4 (CC)*	0.866 @ 20°/4°	92.13	Sax, 1979
- Xylenes	Xylol	$C_6H_4(CH_3)_2$	Colorless liquid		138.5 (mixed xylenes)	37.8(TOC)* (mixed xylenes)	0.864 @ 20°/4° (mixed xylenes)	106.2	Sax, 1979

*CC = closed cup
TOC = tag open cup

APPENDIX III

TYPICAL CURING AGENTS AND DILUENTS FOR EPOXY RESINS

APPENDIX III

TYPICAL CURING AGENTS AND DILUENTS FOR EPOXY RESINS

Aliphatic Amines

Aminoethylpiperazine*
Bis(hexamethylenetriamine)
Diethylaminopropylamine (DEAPA)
Diethylenetriamine (DETA)*
Iminobispropylamine
Polyglycoldiamine*
Tetraethylenepentamine (TEPA)
Triethylenetetramine (TETA)*

Aromatic Amines

2,6-Diaminopyridine
4,4'-Diaminodiphenyl sulfone (DDS)*
4-Chloro-ortho-phenylenediamine (MOCA)
4,4'-Methylenedianiline (MDA)*
m-Phenylenediamine (MPDA)
Dimethylaniline (DMA)

Acids/Anhydrides

Lewis acids
Chlorendic anhydride
Dodecenylsuccinic anhydride (DDSA)
Hexahydrophthalic anhydride*
Maleic anhydride (MA)
Nadic methyl anhydride*
Phthalic anhydride*
Pyromellitic dianhydride (PMDA)
Tetrahydrophthalic anhydride (THPA)
Trimellitic anhydride (TMA)

Polyamides

Amides of dibasic acids*

*Used in epoxy resins during 1983/1984 Ontario industry survey; others on this list may also be used in Ontario.

Polysulfides

Mercaptan compounds*

Amino and Phenol
Formaldehyde Resin Curing Agents

Melamine-formaldehyde*
Phenol-formaldehyde*
Urea-formaldehyde*

Catalytic Curing Agents

α-Methylbenzyldimethylamine
Boron trifluoride monoethylamine (BF_3MEA)*
Dicyandiamide (Dicy)*
Dimethylaminomethylphenol (DMP-10)
2,4,6-Tris(dimethylaminomethyl)phenol (DMP-30)*
Ethyl diethanolamine
Benzyldimethylamine*

Reactive Diluents

Alkyl glycidyl ether*
Allyl glycidyl ether (AGE)
n-Butyl glycidyl ether* (BGE)
Cresyl glycidyl ether
Diglycidyl ether (DGE)
Isopropyl glycidyl ether
Phenyl glycidyl ether

Nonreactive Diluents
(Thinners and Solvents)

Ketones

Acetone*
Diacetone alcohol
Isophorone
Methyl ethyl ketone*
Methyl isobutyl ketone*

Esters

Ethyl acetate
n-Butyl acetate
Cellosolve acetate

Ether Alcohols

Methyl cellosolve*
Ethyl cellosolve
Butyl cellosolve
Ethyl carbitol
Butyl carbitol

Glycol Alcohols

Ethylene glycol*

Chlorinated Solvents

1,1,1-Trichloroethane*
Chloroform
Methylene chloride*

Aromatic Hydrocarbons

Styrene
Toluene*
Xylenes*

APPENDIX IV

COMMERCIAL EPOXY
RESIN FORMULATIONS
(Courtesy Dow, Ciba-Geigy & Shell)

D.E.R.* Epoxy Resins

Liquid Epoxy Resins (Bisphenol A-Type)

Resins	Epoxide Equivalent Weight	Viscosity	Color Max (Gardner)	Non-Volatile (%)	Principal End Use
D.E.R. 317	192-208	10,000-25,000	5	100	Fast reacting liquid resin for adhesive applications
D.E.R. 324	197-205	800-900	3	100	Diluted resin for use in coatings, adhesives, civil engineering, and construction applications
D.E.R. 330	177-188	7,000-10,000	3	100	Lowest viscosity standard liquid bisphenol A type resin for potting, adhesives, electrical laminates, and solvent free coatings
D.E.R. 331	182-192	11,000-14,000	1	100	Standard low molecular weight liquid bisphenol A type resin for potting, adhesives, electrical laminates, and civil engineering
D.E.R. 332	172-176	4,000-6,000	1	100	Exceptionally high purity low molecular weight resin for applications requiring best color, low viscosity, and improved elevated temperature performance (Bisphenol A type)
D.E.R. 333	193-203	2,300-7,000	3	95-97	Precatalyzed liquid resin used for manufacture of solid solution resin for coatings and electrical laminates
D.E.R. 337	230-250	400-600[1]	3	100	Low molecular weight semi-solid resin used in adhesives and coatings
D.E.R. 383	176-185	9,000-11,500	2	100	Liquid resin providing reduced viscosity and extended pothife for filament winding and encapsulation

Solid Epoxy Resins and Solutions (Bisphenol A-Type)

Resins	Epoxide Equivalent Weight	Viscosity	Color Max (Gardner)	Non-Volatile (%)	Solvent Composition	Mettler Softening Point C	Principal End Use
D.E.R. 661	475-575	N.A.	3[2]	100	N.A.	75-85	Low molecular weight solid resin used for coatings systems and electrical laminate pre pregs
D.E.R. 661 A80	475-575[3]	3500-8000	2	79-81	Acetone	N.A.	Low molecular weight solid resin in acetone solution for electrical laminates
D.E.R. 662	575-700	900-2000[4]	1[2]	100	N.A.	84-91	Low molecular weight standard solid resin for glass sizing
D.E.R. 664	875-975	4000-9000[4]	3[2]	100	N.A.	95-100	Medium molecular weight standard resin used in preparation of fatty acid esters for automotive primers, appliance primers, maintenance finishes, etc.
D.E.R. 667	1600-2000	30,000-100,000[4]	3[2]	100	N.A.	120-135	Medium molecular weight standard resin used with MF and PF resins for can and coil coatings
D.E.R. 671 EEK 75	425-550[3]	2000-10,000	2	74-76	Glycol Ether 70% MIBK 30%	N.A.	Solution of low softening point solid resin for two package coating systems
D.E.R. 671 EEX 75	425-550[3]	Z-Z3[5]	5	74-76	Glycol Ether 70% Xylene 30%	N.A.	Solution of low softening point solid resin for two package coating systems
D.E.R. 671-X75	425-550[3]	4500-10,000	2	74-76	Xylene	N.A.	Solution of low softening point solid resin designed for two package coating systems
D.E.R. 671-X88 75	425-550[3]	2500-5000	2	74-76	MIBK 65% Xylene 35%	N.A.	Solution of low softening point solid resin designed for two package coating systems
D.E.R. 671 EE75	425-550[3]	4000-20,000	2	74-76	Glycol Ether	N.A.	Solution of low softening point solid resin designed for two package coating systems
D.E.R. 671-T75	425-550[3]	2200-10,000	2	74-76	Toluene	N.A.	Solution of low softening point solid resin designed for two package coating systems
D.E.R. 684-EK40	N.A.	U-Y[5]	3	39-41	MEK	N.A.	Ultra high molecular weight solution resin for metal primers

Solid Epoxy Resins for Powder Coatings (Bis A- and/or Bis A-/Bis F-Types)

Resins	Epoxide Equivalent Weight	Viscosity	Color Max (Gardner)	Non-Volatile (%)	Solvent Composition	Mettler Softening Point C	Principal End Use
D.E.R. 643U	500-575	2000-5000[4]	2[2]	100	N.A.	90-98	Novolac modified, medium molecular weight Bis A-/Bis F type resin for powder coatings having high chemical resistance and excellent electrical properties
D.E.R. 662	575-700	900-2000[4]	2[2]	100	N.A.	84-94	Low molecular weight solid resin used primarily as an additive to reduce melt mix viscosity or to improve flow
D.E.R. 663U	730-840	2500-4500[4]	2[2]	100	N.A.	92-102	Low molecular weight standard solid resin for powder coatings and esterification
D.E.R. 664U	875-975	4000-9000[4]	2[2]	100	N.A.	95-100	Medium molecular weight standard resin for powder coatings
D.E.R. 672U	750-850	20,000-50,000[4]	3[2]	100	N.A.	110-120	Novolac modified, medium molecular weight Bis A-/Bis F type resin for powder coatings having high chemical resistance and excellent electrical properties

Flexible Epoxy Resins

Resins	Epoxide Equivalent Weight	Viscosity	Color Max (Gardner)	Non-Volatile (%)	Principal End Use
D.E.R. 732	305-335	55-100	1	100	Aliphatic diepoxide which, when blended with conventional resins, imparts flexibility, elongation, and improved impact. A viscosity reducer for standard liquid resins
D.E.R. 736	175-205	20-50	1	100	A shorter chain aliphatic diepoxide than D.E.R. 732. Gives slightly less flexibility, impact, and elongation with some improvement over D.E.R. 732 in heat distortion temperature and chemical resistance

Brominated Epoxy Resins and Solutions

Resins	Epoxide Equivalent Weight	Viscosity cps at 25 C	Color Max (Gardner)	Non-Volatile (%)	Solvent Composition	Mettler Softening Point C	Bromine Content (%)	Principal End Use
D.E.R. 511 A80	445-530[3]	1000-4000	9	79-81	Acetone	N.A.	19-22	Acetone solution of low molecular weight brominated resin for fire retardant electrical laminates
D.E.R. 521 A80	430-475[3]	1000-4000	5	79-81	Acetone	N.A.	19-21.5	Acetone solution of low molecular weight brominated resin for fire retardant electrical laminates
D.E.R. 542	385-355	Semi-solid	12	100	N.A.	52-62	44-49	For use in electrical laminates where maximum bromine content is needed to offset large ratios of hardener. Also for blending with conventional epoxy resins

Epoxy Novolac Resins and Solutions

Resins	Epoxide Equivalent Weight	Viscosity	Color Max (Gardner)	Non-Volatile (%)	Principal End Use
D.E.N.* 431	172-179	1100-1700 (at 52 C)	3	100	Lowest viscosity epoxy novolac resin. Average functionality of 2.2. Used in electrical applications and as additive to conventional epoxy resins.
D.E.N. 438	176-181	30,000-50,000 (at 52 C)	2	100	Higher viscosity standard epoxy novolac resin. Average functionality of 3.6. Very good elevated temperature performance in electrical insulation applications
D.E.N. 438-A 85	176-181[3]	500-1300	2	84-86	Acetone solution of D.E.N. 438
D.E.N. 438-EK 85	176-181[3]	800-1000	2	84-86	Methyl ethyl ketone solution of D.E.N. 438
D.E.N. 438 MK75	176-181[3]	200-600	2	74-76	Methyl isobutyl ketone solution of D.E.N. 438
D.E.N. 439	191-210	4,000-10,000[4]	3	100	A semi-solid epoxy novolac with a functionality of 3.8 and having particular advantage in preparing tacky pre-preg with little or no B staging
D.E.N. 439-EK85	191-210[3]	4,000-10,000	3	84-86	Methyl ethyl ketone solution of D.E.N. 439
D.E.N. 485	165-195	400-1150[4]	N.A.	100	Solid epoxy novolac with a functionality of 5.5. Outstanding high temperature performance in electrical applications and adhesives

Epoxy Hardeners (Curing Agents)

Curing Agents	Amine Hydrogen Equivalent Weight	Viscosity	Color Max (Gardner)	Non-Volatile (%)	Principal End Use
D.E.H.* 20	20.6	5.5-8.5	1	Liquid	Polyamine hardener, diethylene triamine (DETA). Convenient low cost, low viscosity, room temperature cure. For civil engineering applications
D.E.H. 24	24.4[1]	19.5-22.5	3	Liquid	Polyamine hardener, triethylene tetramine (TETA). Similar in application to DETA. Higher boiling point.
D.E.H. 26	27.1	55		Liquid	Polyamine hardener, tetraethylenepentamine (TEPA). Used in two package protective coating systems. Room temperature cure
D.E.H. 29	26.0	300		Liquid	Polyamine hardener (amine blend) similar in application to DETA. Less blush when cured under humid conditions
D.E.H. 30	43	10		Liquid	Technical grade of aminoethyl piperazine (AEP). Short pot life. Improved impact
D.E.H. 40	110-122	N.A.	APHA 100*	N.A.	Solid curing agent for epoxy powder coatings. Accelerated dicyandiamide type. For fast curing decorative systems.
D.E.H. 52	42-47	5000-7000	3		DETA modified with liquid epoxy
D.E.H. 58	38	85-130			DETA modified with Bisphenol-A

Notes

REPRODUCED BY PERMISSION OF DOW CHEMICAL, SARNIA

Ciba-Geigy Araldite Epoxy Resins (Typical of products marketed in Canada)

General Brochure

Specifications for Araldite® Epoxy Resins and Related Products

	CIBA-GEIGY Araldite	Viscosity Canon-Fenske @ 25°C cP	WPE	Epoxy Value eq/100g	Color Max. Gardner (Typical)	Weight/ Gallon, Lb. (Typical)	Diluent
Liquid Resins	502	2100 - 3600	232-250	0.40-0.43	3	9.45	DBP
	506	500 - 700	172-185	0.54-0.58	3	9.45	BGE
	507	500 - 700	185-193	0.52-0.54	7	9.50	CGE
	508	2000 - 5000	400-455	0.22-0.25	5	9.40	Flexibilizer
	509	500 - 700	189-200	0.50-0.53	1	9.3	Ep. 7
	6004	5000 - 6500	179-196	0.51-0.56	2	9.7	
	6005	7500 - 9500	182-192	0.51-0.55	2	9.7	
	6010	12000 - 16000	182-196	0.52-0.55	3	9.7	
	6020	16000 - 20000	192-208	0.48-0.52	3	9.7	
	GY 9513	500 - 700	196-213	0.47-0.51	3	9.1	Ep. 8

	CIBA-GEIGY Araldite	Viscosity (Gardner-Holdt) @ 25°C *	ICI Viscosity cP @ 150°C	WPE	Epoxy Value eq/100g	Color Max. Gardner (Typical)	Softening Point °C	Lbs./ Gal. (Typ.)
Solid Resins	GT 6060	-	550-950[a]	385- 500	0.20 - 0.26	4	60 - 75	9.9
	GT 6084	R-U	-	908-1000	0.10 - 0.11	2	95 - 105	9.9
	GT 6097	Z-Z_2	-	2000-2500	0.04 - 0.05	3	125 - 135	9.8
	GT 7004		3100-4500[b]	714- 833	0.12 - 0.14	1	86 - 96	9.9
	GT 7013	L-P	2200-3200[b]	667- 714	0.14 - 0.15	1	84 - 89	9.9
	GT 7014	N-R	3100-4700[b]	714- 769	0.13 - 0.14	1	86 - 96	9.9
	GT 7071	D-G	-	455- 526	0.19 - 0.22	2	65 - 75	9.9
	GT 7072	G-K	-	556- 714	0.14 - 0.18	2	75 - 85	9.9
	GT 7074	U-W	1000-2000[d]	909-1111	0.09 - 0.11	2	97 - 110	
	GT 7097	X-Z	-	1667-2000	0.05 - 0.06	3	113 - 123	9.8
	GT 9496	N-R	-	714- 833	0.12 - 0.14	-	89 - 98	
	GT 9516	D-H	-	475- 525	0.19 - 0.21	2	65 - 75	
	GT 9545	R-U	1100-2100[c]	875-1025	0.0975- 0.114	2	95 - 105	9.9
	XU 220	P-T	1000-2000[c]	526- 556	0.18 - 0.19	2	85 - 92	9.9
	XU 226	N-R	-	764- 909	0.11 - 0.13	1	85 - 97	
	XU 255		2700-4100[d]	769- 833	0.12 - 0.13	2	106 - 113	9.9

a - Measured @ 130°C

b - Measured @ 150°C

c - Measured @ 175°C

d - Measured @ 200°C

* - 40% N.V. in Butyl Carbitol

(Reproduced by permission of Ciba-Geigy, Mississauga)

Specifications for Araldite® Epoxy Resins and Related Products
Page 2

	CIBA-GEIGY Araldite	Viscosity (Gardner-Holdt) @ 25°C	WPE	Epoxy Value eq/100g	Color Max. (Typ.)	Solids Content	Solvent	Lbs./ Gal. (Typ.)	Flash Point °F
Resin Solutions	GZ 465 A-80	Z_1 - Z_4	455 - 500	0.20 -0.22	3	79-81	Acetone	9.1	81
	GZ 471 X-75	Z_3 - Z_5	455 - 526	0.19 -0.22	3	74-76	Xylene	9.0	88
	GZ 488 E-32	X - Z_1	3333 max.	0.03 max.	3	31-33	Cellosolve Acetate	8.6	123
	GZ 488 N-40	U - Y	3333 max.	0.03 max.	5	39-41	Methyl Ethyl Ketone	7.9	<55
	GZ 497 C-55	Z_3 - Z_5	1667 - 2000	0.05 -0.06	4	54-56	Cellosolve	8.8	110
	GZ 540 X-90	Z_4 - Z_7	233 - 278	0.36 -0.43	3	89-91	Xylene	9.4	115
	GZ 571 CX-80	Z_5 - Z_7	455 - 526	0.19 -0.22	3	79-81	Cellosolve (15%)/ Xylene (5%)	9.4	122
	GZ 571 KX-75	Z_1 - Z_4	455 - 526	0.19 -0.22	3	74-76	Methyl Isobutyl Ketone (16%)/ Xylene (9%)	8.9	84
	GZ 571 T-75	Z_2 - Z_4	455 - 526	0.19 -0.22	5	74-76	Toluene	9.1	49
	GZ 597 ET-55	Z_1 - Z_4	1667 - 2000	0.05 -0.06	4	54-56	Cellosolve Acetate (22.5%)/Toluene (22.5%)	8.8	46
	GZ 597 EX-55	Z_2 - Z_4	1667 - 2000	0.05 -0.06	5	54-56	Cellosolve Acetate (22.5%)/Xylene (22.5%)	8.6	65
	GZ 597 KT-55	Y - Z_3	1667 - 2000	0.05 -0.06	4	54-56	MIBK (22.5%)/Toluene (22.5%)	8.4	<55
	GZ 7071 C-75	Z_2 - Z_6	455 - 526	0.19 -0.22	4	74-76	Cellosolve		110

	CIBA-GEIGY Araldite	Viscosity (Gardner-Holdt) @ 25°C cP	WPE	Epoxy Value eq/100g	% Bromine Content	Softening Point, °C
Flame Retardant Epoxy Systems	CY 8043	3000-4500	217-238	0.42 - 0.46	24-27	-
	LY 8047	350-450[b]	222-244	0.41 - 0.45	18-22	Semi-solid
	LT 8049	-	323-417	0.24 - 0.31	47-50	45-60
	LT 8052	-	286-345	0.29 - 0.35	36-40	35-45
	XU 208	3400-7600[a]	526-667	0.15 - 0.19	47 min.	83-93

a - Measured @ 130°C.
b - Measured @ 70°C.

	CIBA-GEIGY Araldite	Solids Content	Appearance	Viscosity @ 25°C cP	pH	Color Max. Gardner (Typical)	Amine Value	Lbs./ Gal. (Typ.)
Water-Based Systems	XU 253	39-41	White	800- 2000				8.8

	CIBA-GEIGY	Viscosity @ 25°C cP	WPE	Epoxy Value eq/100g	Color Max. Gardner	Chemical Name
Reactive Diluents	Araldite RD 1	1- 5	130-150	0.67-0.77	2	BGE
	Araldite RD 2	15-25	105-154	0.65-0.95	1	Butanediol Diglycidyl Ether
	Araldite DY 023	5-15	175-192	0.52-0.57	4	CGE
	DY 025 (Epoxide 8)	5-15	280-315	0.32-0.36	<1	-
	DY 027 (Epoxide 7)	5-15	215-235	0.43-0.47	<1	-

	CIBA-GEIGY Araldite	Epoxy Value eq/100g	WPE	Viscosity @ 25°C cP	Color Max. Gardner (Typical)
Cycloaliphatics	CY 179	0.70-0.76	131-143	350- 450	1
	CY 184	0.55-0.63	159-182	700-1100	1

Specifications for Araldite® Epoxy Resins and Related Products
Page 4

	CIBA-GEIGY Araldite	Epoxy Value eq/100g	WPE	Color* Max. Gardner (Typical)	Softening Point, °C	Viscosity @ 130°C cP	Lbs./ Gal. (Typ.)
Epoxy Cresol Novolac Resins	ECN 1235	0.44 min.	230 max.	7	32- 42	-	9.3
	ECN 1273	0.43-0.46	215-300	6	65- 75	1000-2700	9.7
	ECN 1280	0.43 min.	235 max.	6	76- 84	2500-7000	9.8
	ECN 1299	0.41-0.45	220-245	6	85-100	5000-15000	9.9

* 50% solids in toluene.

	CIBA-GEIGY Araldite	Epoxy Value eq/100g	WPE	Viscosity @ 25°C	Color Max. Gardner (Typical)	% Solids
Epoxy Phenol Novolac Resins	EPN 1138	0.55-0.57	176-181	35000-70000[b]	2	100
	EPN 1138 A-85	0.55-0.57[a]	176-181[a]	500-1200	2	85
	EPN 1139	0.56-0.58	172-179	1100- 1700[b]	3	100

a - On a solids basis.
b - Measured @ 125°F.

Multifunctionals	CIBA-GEIGY	Epoxy Value eq/100g	WPE	Softening Point	Viscosity @ 25°C
	0163	0.48-0.54	185-208	66-93°C	-
	0500	0.87-0.95	105-115	-	1500-5000
	0510	0.94-1.05	95-106	-	550-850
	MY 720	0.75-0.85	118-133	-	7000-18000[a]
	PT 810	0.90-0.99	101-111	85-110°C	

a - Measured @ 50°C.
b - Measured @ 120°C.

	CIBA-GEIGY Araldite	Color Max. Gardner (Typical)	Viscosity @ 25°C cP	Active Hydrogen Equivalent Weight	Melting Point	Weight Lbs./Gal. (Typical)
Amine Hardeners	XU 205	-	2000- 5000	54- 58	-	9.0
	HY 830	-	3000- 6000	112	-	9.3
	HY 837	3	2700- 3700	68	-	8.2
	HY 850	-	18000-25000	112	-	9.4
	HY 943	3	3300- 6000	38	-	9.0
	HY 956	3	290- 500	47	-	8.8
	HT 972	10	-	49.5	88-92°C	9.8
	HT 976 (Eporal)	-	-	63	170-180°C	-
	HY 2964	2	40- 70	92- 95	-	8.8
	HY 2969	12	700- 900	115	-	9.3

	CIBA-GEIGY	Amino Nitrogen % Solids Basis	Amine Value Solids Basis	Viscosity @ 25°C Gardner-Holdt	Color Max. Gardner (Typical)	Solids Content (Typ.)	Lbs./ Gal. (Typ.)
Polyamide Hardeners	Lancast A	-	457	350 - 885	11	-	-
	HZ 800 CX-60	2.20	85- 95	Z - Z_{3a}	12	59-61	7.8
	HY 815	5.75- 6.15	230-246	Z_3 - Z_9	12	100	8.1
	HZ 815 C-70	5.75- 6.15	230-246	Z_1 - Z_3	12	69-71	7.8
	HZ 815 T-70	5.75- 6.15	230-246	V - Z_{a}	12	69-71	7.8
	HZ 815 X-70	5.75- 6.15	230-246	V - Z_{a}	12	69-71	7.8
	HY 825	8.25- 9.00	330-360	Z_5 - Z_{6a}	12	100	8.1
	HY 840	8.75-10.00	350-400	Z_2 - Z_6	12	100	9.9
	HY 955	12.5 -15.8		500 - 900 cP	12	100	8.1
	HY 9130		350-400	240 - 500 cP	12	100	7.9

a - Measured @ 40°C.

(Reproduced by permission of Shell)

EPON®/EPONOL® Resins
EPON® Curing Agents

Come to Shell for answers

EPON/EPONOL® Resins/Curing Agents

Specification Guide

for 2 part system.

EPON® Resins — Liquids

	Specifications			Typical Property
	Viscosity[1,2] Poises	Color Gardner Max[1]	Epoxide Equivalent Weight[1]	lbs/gal Avg.
EPON Resin 813	5-7	5	180-195	9.5
815	5-7	5	175-195	9.5
826	65-95	2	178-186	9.7
828	110-150	3	185-192	9.7
829	30-70[4]	3	193-203[4]	9.6
830	170-225	4	190-198	9.7
8132	5-7	4	195-215	9.2
8201	50-65	4	180-195	9.7
8280	110-150	3	185-195	9.7

EPON Resins — Solids

		Specifications		Typical Properties	
Fusion Solids	Viscosity Centipoise[1,4]	Color Pt-Co Max[1,13]	Epoxide Equivalent Weight[1]	Viscosity[1,5] Gardner-Holdt	lbs/gal (68°F)
EPON Resin 1001F	5.1-9.6	200	450-550	E - I	10.2
1002F	9.2-13.6	200	600-700	J - N	10.2
1004F	15-25	200	800-950	P - U+	10.2
1007F	50-100	200	1700-2300	Y - Z_2	10.3
1009F	100-250	200	2300-3800	Z_2 - Z_5	10.3
Powder Coating Solids					
EPON Resin 2002	10-17	100	675-760		
2004	18-27	100	875-975		
2002-FC-10[16]	—	—	760-875		
2024[17]	17-26	100[14]	850-950		

EPON Resins — Solutions

				Specifications			Typical Property
	% W Solids ± 1%	Solvent[2]	Viscosity Gardner-Holdt[1,5]	Color Gardner Max[1]	Epoxide Equivalent Weight[1,6]	lbs/gal Avg.
EPON Resin 834-K-90	90	Oxitol®	Z_4 - Z_8	4	230-280[12]	9.6
834-X-80	80	Xylene	R - Y	4	230-280	9.2
834-X-90	90	Xylene	Z_4 - Z_8	4	230-280	9.4
836-A-85	85	Acetone	W - Z_1	4	280-335	9.1
836-C-75	75	MIBK	L - U	4	280-335	8.9
1001-A-80	80	Acetone	Z_1 - Z_6	4	450-550	9.2
1001-B-80	80	MEK	Z_1 - Z_6	4	450-550	9.1
1001-CX-75	75	MIBK/Xylene 65:35	Z_1 - Z_6	4	450-550	9.1
1001-FT-75	75	N-butyl alcohol/ Toluene 50:50	Z_1 - Z_6	4	450-550[12]	9.1
1001-K-75	75	Oxitol	Z_1 - Z_6	4	450-550[12]	9.4
1001-T-75	75	Toluene	Z_2 - Z_7	4	450-550	9.1
1001-X-75	75	Xylene	Z_2 - Z_7	4	450-550	9.1
1007-CT-55	55	MIBK/toluene 50:50	Z - Z_4	5	1600-2300	8.4
1007-KT-55	55	Oxitol/toluene 50:50	Z_1 - Z_4	5	1600-2300	8.8
1009-DU-40	40	DAA/Cyclo Sol® 53 50:50	W - Z_1	5	2300-3800	8.3

EPON Resins — Brominated Solutions

					Specifications				Typical Property
	% W Solids ± 1%	Solvent	Viscosity Gardner-Holdt[1,5]	Poises[1,3]	Color Gardner Max[1]	Epoxide Equivalent Weight[1,6]	Bromine Content % W	lbs/gal Avg.
EPON Resin 1120-A-80	80	Acetone	V - Z_1	10-30	4	450-550	19-21	10.3
1123-A-80	80	Acetone		10-30	5	410-440	18-21.5	10.1-10.4

EPON Resins — Specialties and Multifunctional

	Specifications					Typical Property
	Viscosity Gardner-Holdt[5]	Poises[2]	Color Gardner Max[1]	Epoxide Equivalent Weight[3,4]	%w Solids ± 1%	lbs/gal Avg.
EPON Resin 825	—	40-60	1	172-178		9.7
834	O-V	—	5	230-280		9.7
836	A_1 - B	0.3-0.7	5	290-335		9.7
841	—	110-150	3	185-192		9.7
871	—	4-9	12	390-490[15]		8.2
872	—	15-38	10	650-750[15]		9.0
872-X-75	X - Z_3	15-38	10	650-750[15]	75	8.5
(Multifunctional) 1031	Z_2 - Z_7	—	—	200-240		—
(Multifunctional) 1031-B-80	Z_2 - Z_7	—	—	200-240	80	9.6

EPONOL® Resins

	Specifications				Typical Property
	% W Solids ± 1%	Solvent	Viscosity Gardner-Holdt[4,5]	Color Gardner Max[1]	lbs/gal Avg.
EPONOL Resin 52-B-40	40	MEK	W - Y	6	7.9
53-B-40	40	MEK	X - Z_4	6	7.9
53-L-32	32	Cellosolve Acetate[9]	Z - Z_5	6	8.7
55-B-40	40	MEK	Z_4 - Z_8	6	7.8
55-BK-30	30	MEK/Oxitol 75:25	W - Z	6	7.7
55-L-32	32	Cellosolve Acetate[9]	Z_4 - Z_8	6	8.7

Bisphenol — A

	Specifications				
	% W Bromine	Freezing Point, C.° Min.[10]	Free Phenol % W. Max.	Iron Content PPM Max.	Color Pt-Co Max.
Shell Bisphenol A (resin grade)	—	153.5	0.2	1.5	100[11]
Shell Bisphenol A (polymer grade)	—	156.5	0.02	1.0	40[11]

Intermediates/Diluents

	Specifications			Typical Properties		
	Epoxide Equivalent[3]	Viscosity Centipoises[1,2]	Color Gardner Max[1]	Epoxide Equivalent[3]	Viscosity Centipoises[1,2]	Color Gardner Max[1,6]
Butyl glycidyl ether				130-135	3 max.	1
Cardura® E 10	244-256	5-10	2			
VV® 10				—	1.9	1

SPECIAL STORAGE REQUIREMENTS

Most of the Shell Chemical products listed on this data chart require no special storage precautions. Those which have special storage requirements and tendencies are given below.

Products	Special Storage Requirements/Tendency
EPON Resin 1001F	Subject to cold flow, should be stored below 60°F to prevent sintering (Epon Resin 1002 is less susceptible).
EPON Resins 813, 815, 825, 826, 8132 EPON Curing Agents Y and Z	May crystallize on standing or in storage; may be reliquefied by warming at 120°F
EPON Resin 829	Subject to moderate increase in epoxide equivalent weight; determine epoxide content (perchloric acid method recommended) before using.
EPON Curing Agent P-104 and P-108	To prevent sintering, store below 60°F in a dry place.
EPON Resin 871, 872 and 872-X-75	For best results store below 60°F.
EPON Curing Agents H-1, H-2, H-3, DPC-101, P-104 and P-108	Color tends to increase with age.

FOOTNOTES for EPON/EPONOL Resins

1. All EPON Resins — liquids, all solutions, all brominated solutions, all EPONOL resins, all intermediates/diluents, EPON Resin 825, 841 and 871 on resin as supplied. EPON Resin 834 on 70% wt. solution in butyl DIOXITOL®; EPON Resin 872 on 75% wt. solution in xylene; EPON Resin 1031 on 80% wt. solution in MEK; all other types on 40% wt. solution in butyl Dioxitol; ASTM D 1544-68 (Gardner Color Scale).
2. ASTM D 445-79 (Kinematic viscosity @ 25°C).
3. Grams of resin containing one gram - equivalent of epoxide. HC-427C-81 (perchloric acid method).
4. All EPON Resin — Solids on 40% wt. solution in MEK.
5. ASTM D 1725-62 (Gardner-Holdt viscosity @ 25°C).
6. Based on resin solution at time of shipment.
7. Solvent blend ratios are on a weight basis.
8. On base resin.
9. Trademark, Union Carbide Corporation
10. ASTM D-1493-67 (Test for Solidification point).
11. Absorbance of 50 grams/70 ml methanol.
12. Because alcohols and glycol ethers have a tendency to react with epoxide groups under certain conditions, we cannot provide a sales specification for this property. A typical epoxide range for EPON 834 alcohol or glycol solutions is 230-300, for EPON 1001F solutions is 450-600 and 1600-3000 units for EPON 1007F solutions.
13. ASTM D 1209-69 (Test for Platinum — Cobalt Color).
14. The color of EPON 2024 is based on a 20% wt. solution in MEK.
15. EEW and viscosity will increase with time. Use oldest lots first and maintain modest inventories.
16. 10% Modaflow masterbatch.
17. Powder grade resin containing 0.5% wt. Modaflow

EPON® Curing Agents

		Chemical Type	Physical State[1]	Equivalent Weight[2]	Recommended Concentration Range, PHR[3]	Specifications: Amine Nitrogen Content % W[4]	Specifications: Color Gardner Max[5]	Specifications: Viscosity 25°C, Poises[14]
EPON Curing Agent	C-111	Polyamine adduct	Liquid	200	50[6]	4.4-5.4	4	Q-U[7]
	C-112	Polyamine adduct	Liquid	200	50[6]	4.4-5.4	4	K-R[7]
	D	Polyamine salt	Liquid	Cures catalytically	10.5-13.5	5.4-6.2	—	4.5-9.5
	H-1	Ketimine	Liquid	52	28	15.5-17.5	5	10 cps max.
	H-2	Ketimine	Liquid	55	30	11-14	8	2-5 cps
	H-3	Ketimine adduct	Liquid	101	54	9.5-11.5	8	2-5
	DPC-101	Amine	Powder	—	2-4[13]	3.6-4.0[15]	—	—
	P-104	Accelerated amine	Powder	—	2-5[13]	1.7-2.1[15]	—	—
	P-108	Accelerated amine	Powder	—	4-6[13]	0.6-0.8[15]	—	—
	U	Polyamine adduct	Liquid	48[8]	20-30	18-21	8	60-150
	Y	Aromatic amine	Liquid	48[8]	25	13-16	—	5-20
	Z	Aromatic amine	Liquid	38[8]	19-21	17-19	—	15-40

EPON Curing Agents — Polyamide

		Chemical Type	Physical State[1]	Equivalent Weight[2]	Recommended Concentration Range, PHR[3]	Specifications: Amine Value[9]	Specifications: Color Gardner Max[5]	Specifications: Viscosity Poises[10]
EPON Curing Agent	V-15	Polyamide	Liquid	240	33-133	230-246	9	31-38
	V-25	Polyamide	Liquid	163	33-133	330-360	9	7-9
	V-40	Polyamide	Liquid	140	33-133	370-400	9	2.5-4.5
	V-50	Amidoamine	Liquid	130	33-133	425-450	10	5-10[11]

EPON Curing Agents — Polyamide Solutions

		Chemical Type	Physical State[1]	Recommended Concentration Range, PHR[3]	Specifications: Amine Value[9]	Specifications: Color Gardner Max[5]	Specifications: Viscosity Poises[12]	Specifications: % W Solids ± 1%
EPON Curing Agent	V-1-ET-60	Polyamide	Liquid	167	51-57	9	5-9	60
	V-1-X-65	Polyamide	Liquid	167	55-62	9	20-30	65
	V-15-X-70	Polyamide	Liquid	79	161-173	9	3-8	70
	V-30-XF-60	Polyamide	Liquid	—	115-130	9	9-14	60

FOOTNOTES for EPON Curing Agents

1. At room temperature.
2. Amount required to react with one mole of epoxide.
3. With EPON Resins 813, 815, 825, 826, 828, 830 and 841.
4. ASTM D-2896-73 (Test for total amine value).
5. ASTM D-1544-68 (Gardner Color Scale).
6. With EPON Resin 1001F solid basis).
7. ASTM D-1725-62 (Gardner Holdt viscosity @ 25°C).
8. Approximate.
9. Amine value, milligrams of KOH equivalent to basic nitrogen content of a one-gram sample, determined by acid-base titration.
10. Poises at 75°C.
11. Poises at 25°C.
12. Poises at 40°C.
13. With EPON Resin 2002, 2004 or 2024.
14. ASTM D-2170-76 (Kinematic viscosity @ 25°C).
15. Alkalinity, meq./gram, determined according to ASTM D-2896-73 (Test for total amine value).

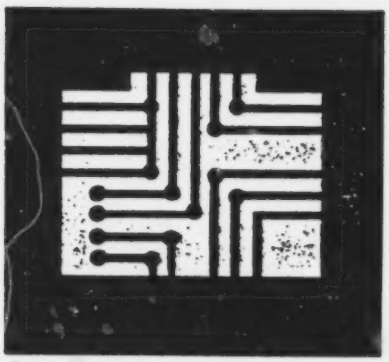
DOT LABEL: Certain products in solution form are classified as Flammable Liquids and their packaging complies with DOT regulations for transporting hazardous materials. Container labels of such products are easily identified by the DOT Diamond displaying a flame pictograph on a red background. The product numbers falling in this class are as follows:

EPON Resin 834-X-80
EPON Resin 1001-A-80
EPON Resin 1001-B-80
EPON Resin 1001-T-75
EPON Resin 1007-CT-55
EPON Resin 1001-X-75
EPON Resin 1001-CX-75
EPON Resin 1001-FT-75
EPON Resin 836-A-85
EPON Resin 836-C-75
EPON Resin 872-X-75
EPON Resin 1007-KT-55
EPON Resin 1120-A-80
EPON Resin 1123-A-80
EPONOL Resin 52-B-40
EPONOL Resin 53-B-40
EPONOL Resin 55-B-40
EPONOL Resin 55-BK-30
EPON Curing Agent C-111
EPON Curing Agent C-112
EPON Curing Agent V-1-ET-60
EPON Curing Agent V-1-X-65
EPON Curing Agent V-15-X-70
EPON Curing Agent V-30-XF-60

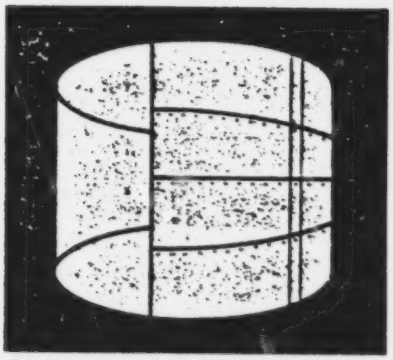
Shell's Westhollow Research Center houses over 1100 technical people conducting research on petroleum and chemical products and processes and on new energy sources. This ultramodern facility, equipped with the latest scientific equipment, is the location for most of the R&D activities of Shell Chemical Company.

SAFETY, HANDLING & STORAGE

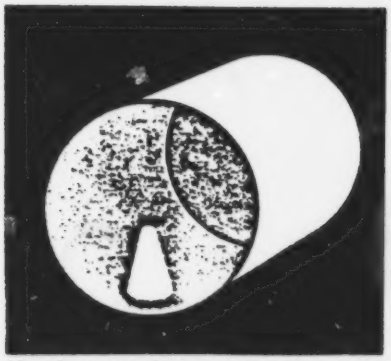
The recommended handling precautions vary according to the resin type. Potential health effects of EPON® and EPONOL® Resins, and EPON® Curing Agents, as indicated by their toxicological properties, vary over a broad range. Descriptive literature, application brochures, ANSI classifications, and handling, safety and storage information, are contained in specific Shell literature. **We strongly recommend that this information be obtained and that all appropriate persons understand this information before handling or use of these products.** Contact your Shell Chemical sales representative or the nearest Shell Chemical sales office for these publications.



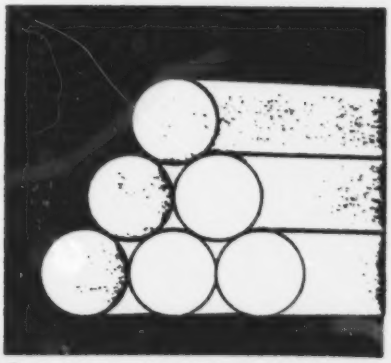
Epon resins are widely used in the production of printed circuit boards for service in computers, communications equipment, air and aerospace craft — and even children's toys and electronic games.



Blending and storage tanks protected with coatings based on Epon and Eponol resins resist chemical corrosion from the inside and environmental attack from the outside.



Manufacturers of beer and beverage cans are using protective coatings based on Epon resins to preserve flavor and prevent corrosion of the container.



Pipes and valves stand up to the elements of nature — and man — when protected by Epon and Eponol resin-based coatings.

APPENDIX V

HEALTH EFFECTS OF EPOXY RESINS AND ASSOCIATED SUBSTANCES

INDEX

Appendix Va - Case Studies of Skin Sensitization/Dermatitis Reactions from Epoxy Resins in the Occupational Environment

Appendix Vb - Case Studies of Respiratory and Blood-Related Problems Associated with Epoxy Resins in the Occupational Environment

Appendix Vc - Summary of Epoxy Resin Carcinogenicity Studies (Berger et al, 1980)

Appendix Vd - Summary of Mutagenicity Results on Epoxy Resins (Hine et al, 1982)

Appendix Ve - Toxicity Data for Curing Agents Commonly Used with Epoxy Resins in Ontario

Appendix Vf - Effects of Skin Contact with Glycidyl Ethers on Humans (NIOSH, 1978b)

Appendix Vg - Toxicity Data for Solvents Commonly Used with Epoxy Resins in Ontario

APPENDIX Va

CASE STUDIES OF SKIN SENSITIZATION/DERMATITIS REACTIONS FROM EPOXY RESINS IN THE OCCUPATIONAL ENVIRONMENT

Industry Type/Process	No. of Workers	Nature of Exposure	Effects	Reference
Construction Industry				
Construction applications	135	Skin contact with resin	Hand dermatosis in 23 workers wearing mostly cotton gloves	Van Putten et al., 1984
Concrete repair	1	Preparation of batches (resin, hardener, and filler) for mixing on site	Allergic dermatitis transformed into atypical psoriasis due to the individual's apparent predisposition to psoriasis	Rycroft, 1980b
Joining gas-main pipes	1	DGEBA resin and hardener (aromatic and aliphatic amine complex)	Dermatitis of hands, forearms and face due to resin (rather than hardener) based on patch test results	Pegum, 1979
Floor-laying	1	Use of glue containing DGEBA epoxy resin with MW340 oligomer	Contact dermatitis after using glue for 1 day	Dahlquist et al., 1979a
Fixing tiles to concrete walls and floors	20	Mixing and using DGEBA resin adhesive	Skin irritation/reddening of forearms; some reddening and itching of whole body	Hosein, 1980
Installation of ceramic tile	3	Epoxy resin	Dermatitis	Gaul, 1967
Sealing of leaky pipes	8	DGEBA resin + butyl glycidyl ether, when heated, emitted fumes	Two weeks after exposure, the men had an acute rash on face, neck, hands and arms with severe edema and itching. Dermatitis cleared in 3 weeks and no further symptoms until next spring on (cont on next page)	Allen and Kaldbey, 1979

Appendix Va
Case Studies of Skin Sensitization/Dermatitis Reactions
from Epoxy Resins in the Occupational Environment - 2

Industry Type/Process	No. of Workers	Nature of Exposure	Effects	Reference
Construction Industry (cont)				
			exposure to sunlight. Photo-sensitivity has persisted for more than 1 year. Effects believed due to bisphenol A component of resin.	
Coatings Industry				
Spraying epoxy powder on metal	1	High-molecular-weight DGEBA resin powder dust containing MW340 oligomer	Dermatitis on face, arms, hands and chest	Bokelund et al., 1980
Mixing of epoxy paints	6	Epoxy resin + solvents	Skin eruptions probably due to epoxy resin	Cohen and Maier, 1974
Artist using varnish	1	Exposure to turpentine and epoxy resin in varnish	Dermatitis believed to be due to both turpentine and epoxy resin	Conde-Salazar et al., 1982
Spray painting with solvent-based epoxy-acrylic resin, alkyl-acrylic melamine resin, and epoxy-polyester resin powder paint	158	Investigations suggest that unintentional heating of painting powder produced photoreactive substances which spread through ventilation system	Seventy-six out of 158 employees acquired facial eczema and 49 have experienced persistent light reactivity	Anderson et al., 1983

Appendix Va
Case Studies of Skin Sensitization/Dermatitis Reactions
from Epoxy Resins in the Occupational Environment - 3

Industry Type/Process	No. of Workers	Nature of Exposure	Effects	Reference
Electrical Industry				
Winding coil for telephone exchanges	1	Polish epoxy resin of the DGEBA type and triethylenetetramine	Allergic contact dermatitis; positive reactions to both epoxy resin and triethylene tetramine	Rudzki, 1978
Gluing transducers	7	Weighing and mixing resin + pyromellitic dianhydride powder	Symptoms included immediate and delayed wheezing and skin rash	Meadway, 1980
Coating Dacron strips, bonding/resining clamps for placement of coils into large rotating generators	19	Epoxy resins	Two workers had sensitization reactions	Gilles, 1976
Fitting of electrodes on lens catheters	1	Epoxy resin	Eye magnifier became contaminated and caused eczema	Hambly and Wilkinson, 1978
Glue assembling of electric motors	1	Epoxy resin	Dermatitis of hands, forearms and face of 2-mo duration	Gaul, 1967
Glue assembling and repairing of electric motors	3	Epoxy resin	Dermatitis	Gaul, 1967
Production of electric energy measuring instruments	1	DGEBA resin + phenyl glycidyl ether	Dermatitis	Rudzki et al., 1983

Appendix Va
Case Studies of Skin Sensitization/Dermatitis Reactions
from Epoxy Resins in the Occupational Environment - 4

Industry Type/Process	No. of Workers	Nature of Exposure	Effects	Reference
Electrical Industry (cont)				
Mixing and application of resins onto circuit boards	?	Epoxy resin + a polysulfide + methylisobutyl ketone (MIBK)	No effects, however it was recommended that epoxy resins be mixed using a fume hood	Roper, 1978
Reinforced Plastics Industry				
Manufacture of plastic tennis rackets	3	DGEBA resin + isophorone diamine (IPD)	Contact dermatitis from both IPD and the epoxy resin	LaChapelle et al., 1978
Manufacture of snow skis and tennis racquets (specifically ski mold area)	20	DGEBA type resin	Allergic sensitization to resin in 50 percent of workers tested (only workers with skin symptoms were tested)	Gunter et al., 1974
Glue fabrication of fiberglass bows	5	Epoxy resin	Dermatitis	Gaul, 1967
Spinners in a glass fiber industry	6	DGEBA type resin containing MW340 oligomer	All developed dermatitis after exposures ranging from 3 weeks to 3 years	Dahlquist et al., 1979b
Laminating with resin	1	DGEBA type resin + phenyl glycidyl ether	Dermatitis on forearms and hands; patch test was positive for phenyl glycidyl ether but negative for the resin	Rudzki et al., 1983

Appendix Va
Case Studies of Skin Sensitization/Dermatitis Reactions
from Epoxy Resins in the Occupational Environment - 5

Industry Type/Process	No. of Workers	Nature of Exposure	Effects	Reference
Reinforced Plastics Industry (cont)				
Finnish ski stick factory	221	DGEBA resins and amine hardeners	Delayed allergy to epoxy resins was confirmed in 15 cases; almost one third of all workers reported skin problems although symptoms in many were not work related	Suhonen, 1983
Artist using epoxy and polyester resin to make RP molds	1	Mixing of DGEBA resin + hardener; application of a layer of epoxy resin and fiberglass matting	No adverse health effects observed from epoxy resin	Geissert, 1977
Miscellaneous Industries/Processes				
Filling undiluted resins, hardeners and reactive diluents in tins from large drums	1	Resin, hardeners and a reactive diluent (glycidyl ester of a synthetic fatty acid)	Severe dermatitis of hands, arms, face, neck and genital and gluteal regions after 9 days exposure; patch test was positive to both resin and reactive diluent	Dahlquist and Fregert, 1979c
Tool setters working with grinding oil	3	Epoxide 7 (reactive diluent of alkyl glycidyl ether type) and/or polyamine in a grinding oil	Three out of four men developed dermatitis from a grinding oil--results are unclear as to whether effects were due to Epoxide 7 or the polyamine	Rycroft, 1980a

Appendix Va
Case Studies of Skin Sensitization/Dermatitis Reactions
from Epoxy Resins in the Occupational Environment - 6

Industry Type/Process	No. of Workers	Nature of Exposure	Effects	Reference
Miscellaneous Industries/Processes (cont)				
Packing shampoos in polyvinyl chloride tubes (without use of gloves)	1	Formaldehyde + epoxy resin	Dermatitis on forearms, face and neck; allergic reaction to formaldehyde in the shampoo and the epoxy resin used as a plasticizer in the PVC tubes	Ancona-Alayon et al., 1976
Assembly of storage batteries	2	Epoxy resin	Dermatitis	Gaul, 1967
Application of prestick signboards on pumps	1	Contact with room temperature hardened resin	Dermatitis	Fregert et al., 1979

APPENDIX Vb

CASE STUDIES OF RESPIRATORY AND BLOOD-RELATED PROBLEMS ASSOCIATED WITH EPOXY RESINS IN THE OCCUPATIONAL ENVIRONMENT

Industry Type/Process	No. of Workers	Nature of Exposure	Sampling Results	Effects	Reference
Coatings Industry					
Pipe coating	29	DGEBA resin containing trimellitic anhydride; exposure to dusts and/or fumes	TMA concentrations of 0.27, 0.1, and 0.14 mg/mm^3 at 0.6, 3.0 and 12.2 m away from powder spray booth*	Twenty workers experienced no symptoms; 4 had mild nasal irritation; and 5 had severe respiratory complaints	Herbert and Orford, 1979
Epoxy resin powder painting	2	Epoxy resin powder containing trimellitic anhydride	-	Hemolytic anemia and repeated hemoptysis	Ahmad et al., 1979
Resin powder painting	1	Epoxy resin containing trimellitic anhydride	-	Asthma attacks	Fawcett et al., 1977
Fusion bond plant where heated pipes are sprayed with epoxy powder	7	Epoxy resin powder containing trimellitic anhydride and silica	-	One worker's exposure to TMA caused lung disease in association with severe anemia. All 7 workers examined had elevated antibody levels demonstrating antigenic potential of TMA	Rivera et al., 1981
Epoxy powder sprayed onto heated pipes	2	Spraying epoxy powder containing trimellitic anhydride	-	Lung injury leading to pulmonary edema and anemia	Rice et al., 1977

*Reference does not indicate clearly whether they were personal or area samples or whether they were time-weighted averages or peak concentrations.

Appendix Vb
Case Studies of Respiratory and Blood-Related Problems
Associated with Epoxy Resins in the Occupational Environment - 2

Industry Type/Process	No. of Workers	Nature of Exposure	Sampling Results	Effects	Reference
Coatings Industry (cont)					
Operation of reactor in manufacture of epoxy resin paints	1	Loading of phthalic acid anhydride powder to reactor (hot fumes at hatch door)	-	Aggravation of existing asthma and initiation of delayed asthmatic attacks	Fawcett et al., 1977
Powder paint spraying operations	18	Contaminants in powder paint spray operations	Nuisance particulates (max) = 14.7 mg/m^3; bisphenol A (max) = 1.063 mg/m^3; DGEBA (max) = 0.200 mg/m^3 (personal samples) *	Skin, eye and mucous membrane irritation and mild skin rash	NIOSH, 1979
Mixing epoxy paints	6	Epoxy resin plus cellosolve acetate: Stoddard solvent: toluene:	9.43 - 442 mg/m^3* 33.0 - 761 mg/m^3* 436.0 - 1,236 mg/m^3* (personal and area samples)	Headaches, dizziness, burning eyes, nose and throat and nausea--probably due to solvent levels	Cohen and Maier, 1974
Reinforced Plastics Industry					
Grinding epoxy resin plastic molds	1	DGEBA resin plus phthalic anhydride (exposure to grinding dusts)	-	Immediate and delayed asthmatic response	Ward and Davies, 1982

*Unclear from reference whether all were time-weighted averages or some were peak concentrations.

Appendix Vb
Case Studies of Respiratory and Blood-Related Problems
Associated with Epoxy Resins in the Occupational Environment - 3

Industry Type/Process	No. of Workers	Nature of Exposure	Sampling Results	Effects	Reference
Reinforced Plastics Industry (cont)					
Production of epoxy resin plastics	5	Epoxy resin containing tetrachlorophthalic anhydride (exposure to powdered dust)	-	Recurrent respiratory illness; all workers exhibited significant changes in pulmonary function and physiologic abnormalities, suggestive of an allergic reaction	Schlueter et al., 1978
Epoxy resin glue to laminate cabin windows	1	Liquid DGEBA resin containing triethylene tetramine (fumes from cold curing system; ventilation present but inadequate)	-	Asthmatic reaction requiring hospitalization	Fawcett et al., 1977
Snow ski manufacture (mold room)	25	DGEBA resin plus an amine-modified polyamide plus solvents	Eight-hour TWA exposures of 0.41 - 1.38 ppm as total amines (3-DMAPA) (area and personal samples); no epichlorohydrin detected	Acute respiratory distress in some workers (dry cough, wheezing, chest tightness); also eye, nose and throat irritation	Sargent et al., 1976
Snow ski manufacture (mold room)	25	DGEBA resin plus an amine-modified polyamide plus solvents	-	Work-related respiratory symptoms reported by Sargent et al. (above) were controlled when concentration of 3-DMAPA was maintained below 0.2 ppm	Brubaker et al., 1979

Appendix Vb
Case Studies of Respiratory and Blood-Related Problems
Associated with Epoxy Resins in the Occupational Environment - 4

Industry Type/Process	No. of Workers	Nature of Exposure	Sampling Results	Effects	Reference
Model making at truck engineering and design center	17	Exposures to wood dusts, cured epoxy resin dusts, and solvents	-	No adverse health effects observed	Bolano, 1981
		Cured resin particulates	2.19 to 3.13 mg/m^3		
		Wood dust	0.31 - 0.80 mg/m^3		
		DGEBA resin	up to 0.0004 mg/m^3		
		Bisphenol A	up to 0.0083 mg/m^3 } TWAs		
		MIBK	up to 1.6 mg/m^3		
		Styrene	up to 14.6 $mg/^3$		
		Toluene	31.8 - 58.15 $mg/^3$		

APPENDIX Vc

SUMMARY OF EPOXY RESIN CARCINOGENICITY STUDIES
(Berger et al., 1980)

Route	Test Material	Test Species	Results	Reference
Oral (diet)	"EPON" 828	Rat	No tumors	Hine et al., 1958a
	"EPON" 828, cured	Rat	No tumors	Hine et al., 1958a
	"EPON" 812	Rat	No tumors	Hine et al., 1958a
	"EPON" 1001, cured	Rat	No tumors	Hine et al., 1958a
	"EPON" 1007	Rat	No tumors	Hine et al., 1958a
	"EPON" 828	Mouse	Pulmonary adenoma; incidence not different from controls by X^2 test	Hine et al., 1958b
	"EPON" 1001	Rat	No tumors	Hine et al., 1958a
Intra-peritoneal	Epoxy A	Mouse	Pulmonary adenoma; incidence not statistically different from controls	Hine et al., 1958b
	"EPON" 828	Mouse	Pulmonary adenoma; incidence not statistically different from controls	Hine et al., 1958b
Subcutaneous	"EPON" 1001	Mouse	Pulmonary adenoma; incidence not statistically different from controls	Hine et al., 1958b
	"EPON" 1007	Mouse	Pulmonary adenoma; incidence not statistically different from controls	Hine et al., 1958b
	"EPON" 828	Rat	Fibrosarcoma	Hine et al., 1958b
	"EPON" 828, cured	Mouse	No tumors from disk implantation	Kidd and Screenby, 1960
Dermal	ERL 2774	Mouse	Papilloma, nonmalignant	Weil et al., 1963
			Repeat study; no tumors	Weil et al., 1963
			Repeat study; no tumors	Weil, 1978
			Repeat study, no tumors	Weil, 1978
	50% ERL 2774, 50% EP 205	Mouse	Malignant and non-malignant tumors	Weil, 1978
	77% ERL 2774, 23% EP 206	Mouse	Malignant and non-malignant tumors	
	63% ERL 2774, 37% EP 205	Mouse	Malignant and non-malignant tumors	Weil et al., 1963; Weil, 1978
	"EPON" 828	Mouse	No tumors	Hine et al., 1958b

Appendix Vc
Summary of Epoxy Resin
Carcinogenicity Studies
(Berger et al., 1980) - 2

Route	Test Material	Test Species	Results	Reference
Dermal (cont)	DGEBPA* + 10% ERL 2774	C3H Mouse	No tumors	Holland et al., 1979
		C57BL/6 Mouse	Malignant and non-malignant tumors	Holland et al., 1979
	BECPE**	C3H Mouse	Malignant and non-malignant tumors	Holland et al., 1979
	BECPE	C57BL/6 Mouse	Malignant and non-malignant tumors	Holland et al., 1979

* DGEBPA denotes diglycidyl ether of bisphenol A. Sample contained 0.5 percent phenyl glycidyl ether.
**BECPE denotes bis(2,3-epoxycyclopentyl) ether.

APPENDIX Vd

SUMMARY OF MUTAGENICITY RESULTS ON EPOXY RESINS
(Hine et al., 1981)

Material Tested	Type of Test	Results*	Reference
EPON® resin 828 (liquid)	Ames	-	C. H. Hine (unpublished)**
	Mitotic index - rat lymphocytes	-	C. H. Hine (unpublished)
	Dominant lethal - 3-wk mating	-	C. H. Hine (unpublished)
	Dominant lethal - 8-wk mating	-	C. H. Hine (unpublished)
Epikote® resin 828 (liquid)	Ames	+	Nature, 276, 391 (1978)
DGEBA† (liquid)	Ames	-	C. H. Hine (unpublished)
	Ames	+	Dow/Legator (unpublished)***
	Body fluid analysis	-	Dow/Legator (unpublished)
	Host-mediated assay	-	Dow/Legator (unpublished)
	Micronucleus	-	Dow/Legator (unpublished)
	DNA repair	-	Dow/Legator (unpublished)
	Dominant lethal	-	Dow/Legator (unpublished)
DGEBA-distilled (liquid)	Ames	+	Dow/Legator (unpublished)
	Body fluid analysis	-	Dow/Legator (unpublished)
	Host-mediated assay	-	Dow/Legator (unpublished)
	Micronucleus	-	Dow/Legator (unpublished)
	DNA repair	-	Dow/Legator (unpublished)
	Dominant lethal	-	Dow/Legator (unpublished)
DGEBA + 10% diluent (liquid) (ERL 2774)	Ames	+	ORNL†† (unpublished)
	Chinese hamster ovary cells	+	ORNL (unpublished)
	Cultured human leukocytes	-	ORNL (unpublished)
BECPE††† (liquid) (ERR 4205)	Ames	+	ORNL (unpublished)
	Chinese hamster ovary cells	+	ORNL (unpublished)
	Cultured human leukocytes	-	ORNL (unpublished)
DGE†††† resorcinol (liquid)	Ames	+	ORNL (unpublished)

Appendix Vd
Summary of Mutagenicity
Results on Epoxy Resins
(Hine et al., 1981) - 2

Material Tested	Type of Test	Results*	Reference
DGE neopentylglycol (liquid)	Ames	+	ORNL (unpublished)
	Ames	+	ORNL (unpublished)
	Ames	+	Dow/Legator (unpublished)
	Body fluid analysis	+	Dow/Legator (unpublished)
	Micronucleus	-	Dow/Legator (unpublished)
	DNA repair	+	Dow/Legator (unpublished)
	Host-mediated assay	-	Dow/Legator (unpublished)
	Dominant lethal	+	Dow/Legator (unpublished)
DGE dimethylhydantoin (liquid)	Ames	+	ORNL (unpublished)
Epikote® resin 1001 (solid)	Ames	+	Nature, 276, 391 (1978)
EPON® resin 1001 (solid)	Ames	-	C. H. Hine (unpublished)
Epikote® resin 1002 (solid)	Ames	+	Rank Xerox/Huntingdon (unpublished)
	Cell transformation	+	Rank Xerox/Huntingdon (unpublished)
Epikote® resin 1004 (solid)	Ames	+	Nature, 276, 391 (1978)
EPON® resin 1004 (solid)	Ames	-	C. H. Hine (unpublished)
	Ames	-	C. H. Hine (unpublished)
EPON® resin 1007 (solid)	Ames	-	C. H. Hine (unpublished)

* (+) indicates mutagenic activity, (-) indicates no mutagenic activity.
** University of California, San Francisco
*** University of Texas Medical Branch, Galveston
† Diglycidal ether of bisphenol A
†† Oak Ridge National Laboratory
††† Bis(2,3-epoxycyclopentyl) ether
††††Diglycidyl ether

APPENDIX Ve

TOXICITY DATA FOR CURING AGENTS
COMMONLY USED WITH EPOXY RESINS IN ONTARIO

Curing Agents	Acute Toxicity Data*	Additional Comments
Aminoethylpiperazine	Oral LD_{50} (rat) = 2,140 mg/kg Dermal LD_{50} (rabbit) = 880 mg/kg (Sax, 1979)	- Moderately toxic by oral and dermal routes (Sax, 1979).
Diethylenetriamine (DETA)	Oral LD_{50} (rat) = 1,080 mg/kg Dermal LD_{50} (rabbit) = 1,090 mg/kg (Sax, 1979)	- If a definite odor of this compound can be detected, industrial process control may be inadequate (Clayton, 1981).
Triethylenetetramine (TETA)	Oral LD_{50} (rat) = 4,340 mg/kg Dermal LD_{50} (rabbit) = 820 mg/kg (Sax, 1979)	- Causes primary skin irritation and sensitization. - Exposure to the hot vapour results in respiratory tract irritation. - Animal experimentation indicates an increase in enzyme activity in the kidneys of pregnant guinea pigs and livers of nonpregnant guinea pigs; skin application caused cutaneous alteration at the application site, liver degeneration, congestion of the kidneys and brain, changes in the placenta and fetal death in pregnant animals (Clayton, 1981).
Diaminodiphenyl sulfone (DDS)	Oral LD_{50} (rat) = 1,000 mg/kg Oral LD_{50} (mouse) = 496 mg/kg (Sax, 1979)	- Occupational poisoning has not been reported; toxic effects from therapeutic use are anemia, fever and dermatitis (Stecher, 1968). - Moderate doses can cause neuritis, dermatitis and hepatitis. - Experimentally tumorigenic (Sax, 1979).
4,4'-Methylenedianiline (MDA)	Oral LD_{50} (rat) = 347 mg/kg sc LD_{50} (rat) = 200 mg/kg (Sax, 1979)	- Believed to be a direct heptotoxin, and has produced cases of occupational hepatitis (McGill and Motto; 1974). - Some indication of being a possible carcinogen and tumorigen (Sax, 1979). - A suspected carcinogen based on animal studies (Steinhoff and Grundman, 1970).

Appendix Ve
Toxicity Data for Curing Agents
Commonly Used with Epoxy Resins in Ontario - 2

Curing Agents	Acute Toxicity Data*	Additional Comments
Hexahydrophthalic anhydride	Appears to have low toxicity by ingestion (Sax, 1979).	- Primarily a skin irritant and possibly a skin sensitizer; vapours are irritating to the skin and mucous membranes; particularly dangerous to the eyes. - Inhalation of high concentrations may result in serious injury to respiratory system (Sax, 1979).
Nadic methylanhydride	No data located.	
Phthalic anhydride	Oral LD_{50} (rat) = 4,020 mg/kg (Sax, 1979)	- Causes skin irritation, burning and chronic eye and upper respiratory tract irritation (Fawcett et al., 1977). - A recognized irritant to the respiratory tract; asthma has been reported both immediate and latent (Fawcett et al., 1977; Ward and Davies, 1983).

*sc = subcutaneous; LD_{50} = lethal dosage to 50 percent of population.

APPENDIX Vf

RESULTS OF REPORTS ON THE EFFECTS OF SKIN CONTACT WITH GLYCIDYL ETHERS ON HUMANS (NIOSH, 1978b)

Compound*	Exposure Concentration in Liquid Solution (percent)	Exposure Duration	Effects	Reference
AGE	-	300 hours	Dermatitis in 10/20 exposed	Hine, C. H., Kodama, J. K., Wellington, J. S., Dunlap, M. K., and Anderson, H. H. The toxicology of glycidol and some glycidyl ethers. AMA Arch Ind Health 14:250 - 264, 1956.
BGE	-	3 months	Dermatitis in 0/8 exposed	Ibid.
BGE	100.0	48 hours	Severe irritation in 5/5 exposed	Lea, W. A., Jr., Block, W. B., and Cornish, H. H. The irritating and sensitizing capacity of epoxy resins. Arch Dermatol 78:304 - 308, 1958.
BGE	10.0	-	Positive patch tests with 10 percent BGE in 19/24 exposed	Kligman, A. M. The identification of contact allergens by human assay--III. The maximization test--A procedure for screening and rating contact sensitizers. J Invest Dermatol 47:393 - 409, 1966.
BGE	10.0	48 hours	Irritation in 17/25; positive patch tests with 12.5 percent BGE in 5/25 exposed	Lea, W. A., Jr., et al. 1958.
BGE	5.0	48 hours	Irritation in 8/25 exposed	Ibid.
BGE	2.5	48 hours	Irritation in 1/25 exposed	Ibid.
BGE	1.25	48 hours	Irritation in 0/25 exposed	Ibid.
DGE	-	a few months	No dermatitis reported	Hine, C. H., et al., 1956.
IGE	-	a few months	No dermatitis reported	Ibid.
PGE	-	600 hours	Dermatitis in 13/20 exposed	Ibid.
PGE	3.0	-	Dermatitis in 12/18; positive patch tests with 0.001 to 1 percent PGE in 8/15 with dermatitis	Zschunke, E., and Behrbohm, P. Eczema due to phenoxypropenoxide and similar glycidyl ethers. Dermatol Wochenschr 151:480 - 484, 1965 (Ger).

*AGE = Allyl Glycidyl Ether; BGE = Butyl Glycidyl Ether; DGE = Diglycidyl Ether; IGE = Isopropyl Glycidyl Ether; PGE = Phenyl Glycidyl Ether

APPENDIX Vg

TOXICITY DATA FOR SOLVENTS
COMMONLY USED WITH EPOXY RESINS IN ONTARIO

Chemical	Acute Toxicity Data*	Additional Comments
Acetone	Oral LD_{50} (rat) = 9,750 mg/kg Dermal LD_{50} (rabbit) = 20 000 mg/kg ip LD_{50} (mouse) = 1,297 mg/kg Inhal TC_{LO} (human) = 500 ppm + eye symptoms (Sax, 1979, p 335)	- Moderate toxicity by oral, intraperitoneal and inhalation routes; very low by dermal routes (Sax, 1979, p 335). - Accidental overexposure to acteone is rare in industry; exposure to 1,000-ppm vapour produces only slight eye, nose and throat irritation. - Concentrations in excess of 10 000 ppm are likely to cause CNS depression and narcotic effects (Clayton, 1981, p 4726).
Methyl cellosolve (ethylene glycol monoethyl ether)	Oral LD_{50} (rat) = 3.0 g/kg Dermal LD_{50} (rabbit) = 3.5 g/kg (Sax, 1979, p 475)	- Moderately toxic by dermal and oral routes; animal experiments indicated exposure to air saturated with cellosolve for periods of 18 to 24 hours may produce congestion and edema of the lungs, and congestion of the kidneys. - No cases of occupational poisoning have been reported (Sax, 1979, p 475).
Methylene chloride	Oral LD_{50} (rat) = 2,136 mg/kg ip LD_{50} (mouse) = 1,500 mg/kg sc LD_{50} (mouse) = 6,440 mg/kg Inhal LD_{LO} (guinea pig) = 5,000 ppm for 2 hours Inhal TC_{LO} (humans) = 500 ppm for 8 hours + blood problems Prolonged inhal of 500 ppm + CNS problems (Sax, 1979)	- Toxic effect, primarily narcosis; exposure to very high concentrations may lead to rapid unconsciousness and death. - Industrial exposure has been remarkably free of serious adverse effects. - Mildly irritating to the skin if allowed to evaporate (rabbit). - Does not appear to present a practical risk of carcinogenisis in humans at currently acceptable levels (Sax, 1979).
m-Xylene	Oral LD_{50} (rat) = 5,000 mg/kg Inhal LC_{LO} (rat) = 8,000 ppm for 4 hours ip LD_{50} (rat) = 2,000 mg/kg sc LD_{LO} (rat) = 5,000 mg/kg (Sax, 1979)	- Xylenes appear to be more acutely toxic than benzene or toluene (Sax, 1979). - When inhaled at high concentrations, may cause dilation of the superficial blood vessels, disturbed vision, dizziness, tremors, salivation, cardiac stress, CNS depression, respiratory difficulties, confusion and coma. - Direct eye contact can cause conjunctivis and corneal burns.

Appendix Vg
Toxicity Data for Solvents
Commonly Used with Epoxy Resins in Ontario - 2

Chemical	Acute Toxicity Data*	Additional Comments
m-Xylene (cont)		- Skin irritant and defatting agent; may cause dermatitis. - Chronic exposure - conjunctivitis of the eyes, and drying of the nose, throat and skin; inhalation of vapours may cause CNS excitation and then depression, characterized by paresthesia, tremors, apprehension, impaired memory, weakness, nervous irritation, giddiness, headache, anorexia, nausea, and may lead to anemia and mucosal hemorrage; also hyperplasia, liver enlargement, necrosis and nephrosis (Clayton, 1981).
Methyl ethyl ketone (MEK) (butanone)	Oral LD_{50} (rat) = 3,400 mg/kg Dermal LD_{50} (rabbit) = 13 000 mg/kg (Sax, 1979, p 438)	- Low toxicity via oral route and low by dermal route (Sax, 1979, p 438). - Slightly more irritating to the mucous membranes and eyes than acetone; CNS depression can occur at high atmospheric concentrations; exposure to 100 ppm is sufficient for an identifiable odor and produces mild irritation to the nose and throat. - Prolonged skin contact may produce dermatitis. - May predispose the liver to injury from hepatotoxins (Clayton, 1981, p 4730).
Methyl isobutyl ketone (MIK)	Oral LD_{50} (rat) = 2,080 mg/kg Inhal LC_{LO} (rat) = 4,000 ppm for 15 minutes Ip LD_{50} (mouse) = 268 mg/kg (Sax, 1979, p 750)	- Principal hazard is inhalation; exposure to concentrations of 200 to 400 ppm is irritating to the eyes, nose and throat; levels of 100 to 500 ppm produce gastrointestinal effects such as nausea, vomiting, appetite loss and diahhrea; levels of 1,000 ppm produce CNS depression. - Causes skin defatting and dermatitis (Clayton, 1981, p 4750).

Appendix Vg
Toxicity Data for Solvents
Commonly Used with Epoxy Resins in Ontario - 3

Chemical	Acute Toxicity Data*	Additional Comments
Toluene	Inhal TC_{LO} (human) = 200 ppm + CNS effects Inhal TC_{LO} (man) = 100 ppm + psychotropic effects Oral LD_{50} (rat) = 5,000 mg/kg Inhal LC_{LO} (rat) = 4,000 ppm for 4 hours ip ID_{50} (rat) = 1,640 mg/kg Inhal LC_{50} (mice) = 5,300 mg/kg Dermal LD_{50} (rabbit) = 14 000 mg/kg (Sax, 1979)	- Acute poisonings are rare in industry. - Inhalation at 200 ppm may cause impairment of coordination and reaction time; concentrations up to 800 ppm can increase these effects and initiate them sooner; at 200 to 500 ppm headache, nausea, loss of appetite, a bad taste, lassitude, impairment of coordination and reaction. - Causes rapid and intense burning of the cornea and toxic effects on the conjunctiva. - Skin contact may cause drying and defatting, leading to fissured dermatitis; it is not a sensitizer. - Symptoms of chronic poisoning include anemia, and leukopenia, and bone marrow hyperplasia (Sax, 1979; Clayton, 1981).
1,1,1-Trichloroethane (methyl chloroform)	ip LD_{50} (mice) = 4,700 mg/kg Oral LD_{50} (dog) = 750 mg/kg Oral LD_{50} (rabbit) = 5,660 mg/kg 920 ppm for 70 minutes causes CNS effects in humans Inhal LC_{LO} (man) = 27 000 mg/m^3 for 10 minutes (Sax, 1979)	- Moderately toxic by oral and intraperitoneal routes. - May cause heartbeat irregularities (Sax, 1979).

*sc = subcutaneous
ip = intraperitoneal

LD_{50} = lethal dosage to 50 percent of population
LC_{50} = lethal concentration to 50 percent of population
LD_{LO} = lowest lethal dosage
TC_{LO} = lowest published toxic concentration

APPENDIX VI

NIOSH AIR MONITORING AND ANALYTICAL PROCEDURES FOR SOME SUBSTANCES ASSOCIATED WITH EPOXY RESINS (NIOSH, 1977 - 1980)

INDEX

Appendix VIa - Epichlorohydrin

Appendix VIb - Bisphenol A and Diglycidyl Ether of Bisphenol A

Appendix VIc - Aliphatic Amines in Air

Appendix VId - Ethylenediamine and Diethylenetriamine

APPENDIX VIa

Epichlorohydrin
(1-Chloro-2,3-epoxypropane)

Analyte:	Epichlorohydrin	Method No.: S118
Matrix:	Air	Range: 11.7-43.1 mg/cu m
OSHA Standard:	5 ppm (20 mg/cu m)	Precision ($\overline{CV}_T$): 0.057
Procedure:	Adsorption on charcoal, desorption with carbon disulfide, GC	Validation Date: 5/9/75

1. Principle of the Method

1.1 A known volume of air is drawn through a charcoal tube to trap the organic vapors present.

1.2 The charcoal in the tube is transferred to a small, stoppered sample container, and the analyte is desorbed with carbon disulfide.

1.3 An aliquot of the desorbed sample is injected into a gas chromatograph.

1.4 The area of the resulting peak is determined and compared with areas obtained from the injection of standards.

2. Range and Sensitivity

2.1 This method was validated over the range of 11.7-43.1 mg/cu m at an atmospheric temperature and pressure of 23°C and 765 mm Hg, using a 20-liter sample. Under the conditions of sample size (20 liters) the probable useful range of this method is 2-60 mg/cu m at a detector sensitivity that gives nearly full deflection on the strip chart recorder for a 1-mg sample. The method is capable of measuring much smaller amounts if the desorption efficiency is adequate. Desorption efficiency must be determined over the range used.

2.2 The upper limit of the range of the method is dependent on the adsorptive capacity of the charcoal tube. This capacity varies with the concentrations of epichlorohydrin and other substances in the air. The first section of the charcoal tube was found to hold at least 2 mg of epichlorohydrin when a test atmosphere

containing 43.1 mg/cu m of epichlorohydrin in air was sampled at 0.185 liter per minute for 240 minutes; at that time the concentration of epichlorohydrin in the effluent was less than 5% of that in the influent. (The charcoal tube consists of two sections of activated charcoal separated by a section of urethane foam. See Section 6.2). If a particular atmosphere is suspected of containing a large amount of contaminant, a smaller sampling volume should be taken.

3. Interference

3.1 When the amount of water in the air is so great that condensation actually occurs in the tube, organic vapors will not be trapped efficiently. Preliminary experiments using toluene indicate that high humidity severely decreases the breakthrough volume.

3.2 When two or more compounds are known or suspected to be present in the air, such information, including their suspected identities, should be transmitted with the sample.

3.3 It must be emphasized that any compound which has the same retention time as the analyte at the operating conditions described in this method is an interference. Retention time data on a single column cannot be considered proof of chemical identity.

3.4 If the possibility of interference exists, separation conditions (column packing, temperature, etc.) must be changed to circumvent the problem.

4. Precision and Accuracy

4.1 The Coefficient of Variation ($\overline{CV}_T$) for the total analytical and sampling method in the range of 11.7-43.1 mg/cu m was 0.057. This value corresponds to a 1.1 mg/cu m standard deviation at the OSHA standard level. Statistical information and details of the validation and experimental test procedures can be found in Reference 11.2.

4.2 On the average the concentrations obtained at the OSHA standard level using the overall sampling and analytical method were 0.7% lower than the "true" concentrations for a limited number of laboratory experiments. Any difference between the "found" and "true" concentrations may not represent a bias in the sampling and analytical method, but rather a random variation from the experimentally determined "true" concentration. Therefore, no recovery correction should be applied to the final result.

5. Advantages and Disadvantages of the Method

5.1 The sampling device is small, portable, and involves no liquids. Interferences are minimal, and most of those which do occur can be eliminated by altering chromatographic conditions. The tubes are analyzed by means of a quick, instrumental method.

The method can also be used for the simultaneous analysis of two or more substances suspected to be present in the same sample by simply changing gas chromatographic conditions from isothermal to a temperature-programmed mode of operation.

5.2 One disadvantage of the method is that the amount of sample which can be taken is limited by the number of milligrams that the tube will hold before overloading. When the sample value obtained for the backup section of the charcoal tube exceeds 25% of that found on the front section, the possibility of sample loss exists.

5.3 Furthermore, the precision of the method is limited by the reproducibility of the pressure drop across the tubes. This drop will affect the flow rate and cause the volume to be imprecise, because the pump is usually calibrated for one tube only.

6. Apparatus

6.1 A calibrated personal sampling pump whose flow can be determined within ±5% at the recommended flow rate. (Reference 11.3)

6.2 Charcoal tubes: glass tube with both ends flame sealed, 7 cm long with a 6-mm O.D. and a 4-mm I.D., containing 2 sections of 20/40 mesh activated charcoal separated by a 2-mm portion of urethane foam. The activated charcoal is prepared from coconut shells and is fired at 600°C prior to packing. The adsorbing section contains 100 mg of charcoal, the backup section 50 mg. A 3-mm portion of urethane foam is placed between the outlet end of the tube and the backup section. A plug of silylated glass wool is placed in front of the adsorbing section. The pressure drop across the tube must be less than one inch of mercury at a flow rate of 1 liter per minute.

6.3 Gas chromatograph equipped with a flame ionization detector.

6.4 Column (10-ft x 1/8-in stainless steel) packed with 10% FFAP on 80/100 mesh, acid washed DMCS Chromosorb W.

6.5 An electronic integrator or some other suitable method for measuring peak areas.

6.6 Two-milliliter sample containers with glass stoppers or Teflon-lined caps. If an automatic sample injector is used, the associated vials may be used.

6.7 Microliter syringes: 10-microliter, and other convenient sizes for making standards.

6.8 Pipets: 1.0-ml delivery pipets.

6.9 Volumetric flasks: 10-ml or convenient sizes for making standard solutions.

7. Reagents

7.1 Chromatographic quality carbon disulfide.

7.2 Epichlorohydrin, reagent grade.

7.3 Purified nitrogen.

7.4 Prepurified hydrogen.

7.5 Filtered compressed air.

8. Procedure

8.1 Cleaning of Equipment. All glassware used for the laboratory analysis should be detergent washed and thoroughly rinsed with tap water and distilled water.

8.2 Calibration of Personal Pumps. Each personal pump must be calibrated with a representative charcoal tube in the line. This will minimize errors associated with uncertainties in the sample volume collected.

8.3 Collection and Shipping of Samples

8.3.1 Immediately before sampling, break the ends of the tube to provide an opening at least one-half the internal diameter of the tube (2 mm).

8.3.2 The smaller section of charcoal is used as a back-up and should be positioned nearest the sampling pump.

8.3.3 The charcoal tube should be placed in a vertical direction during sampling to minimize channeling through the charcoal.

8.3.4 Air being sampled should not be passed through any hose or tubing before entering the charcoal tube.

8.3.5 A sample size of 20 liters is recommended. Sample at a flow of 0.20 liter per minute or less. The flow rate should be known with an accuracy of at least $\pm$5%.

8.3.6 The temperature and pressure of the atmosphere being sampled should be recorded. If pressure reading is not available, record the elevation.

8.3.7 The charcoal tubes should be capped with the supplied plastic caps immediately after sampling. Under no circumstances should rubber caps be used.

8.3.8 One tube should be handled in the same manner as the sample tube (break, seal, and transport), except that no air is sampled through this tube. This tube should be labeled as a blank.

8.3.9 Capped tubes should be packed tightly and padded before they are shipped to minimize tube breakage during shipping.

8.3.10 A sample of the bulk material should be submitted to the laboratory in a glass container with a Teflon-lined cap. This sample should not be transported in the same container as the charcoal tubes.

8.4 Analysis of Samples

8.4.1 Preparation of Samples. In preparation for analysis, each charcoal tube is scored with a file in front of the first section of charcoal and broken open. The glass wool is removed and discarded. The charcoal in the first (larger) section is transferred to a 2-ml stoppered sample container. The separating section of foam is removed and discarded; the second section is transferred to another stoppered container. These two sections are analyzed separately. Samples should be analyzed within one week after collection.

8.4.2 Desorption of Samples. Prior to analysis, 1.0 ml of carbon disulfide is pipetted into each sample container. (All work with carbon disulfide should be performed in a hood because of its high toxicity.) Desorption should be done for 30 minutes. Tests indicate that this is adequate if the sample is agitated occasionally during this period. If an automatic sample injector is used, the sample vials should be capped as soon as the solvent is added to minimize volatilization.

8.4.3 GC Conditions. The typical operating conditions for the gas chromatograph are:

1. 50 ml/min (60 psig) nitrogen carrier gas flow
2. 65 ml/min (24 psig) hydrogen gas flow to detector
3. 500 ml/min (50 psig) air flow to detector
4. 175°C injector temperature
5. 215°C manifold temperature (detector)
6. 120°C column temperature

8.4.4 Injection. The first step in the analysis is the injection of the sample into the gas chromatograph. To eliminate difficulties arising from blow back or distillation

within the syringe needle, one should employ the solvent flush injection technique. The 10-microliter syringe is first flushed with solvent several times to wet the barrel and plunger. Three microliters of solvent are drawn into the syringe to increase the accuracy and reproducibility of the injected sample volume. The needle is removed from the solvent, and the plunger is pulled back about 0.2 microliter to separate the solvent flush from the sample with a pocket of air to be used as a marker. The needle is then immersed in the sample, and a 5-microliter aliquot is withdrawn, taking into consideration the volume of the needle, since the sample in the needle will be completely injected. After the needle is removed from the sample and prior to injection, the plunger is pulled back 1.2 microliters to minimize evaporation of the sample from the tip of the needle. Observe that the sample occupies 4.9-5.0 microliters in the barrel of the syringe. Duplicate injections of each sample and standard should be made. No more than a 3% difference in area is to be expected. An automatic sample injector can be used if it is shown to give reproducibility at least as good as the solvent flush method.

8.4.5 Measurement of area. The area of the sample peak is measured by an electronic integrator or some other suitable form of area measurement, and preliminary results are read from a standard curve prepared as discussed below.

8.5 Determination of Desorption Efficiency

8.5.1 Importance of determination. The desorption efficiency of a particular compound can vary from one laboratory to another and also from one batch of charcoal to another. Thus, it is necessary to determine at least once the percentage of the specific compound that is removed in the desorption process, provided the same batch of charcoal is used.

8.5.2 Procedure for determining desorption efficiency. Activated charcoal equivalent to the amount in the first section of the sampling tube (100 mg) is measured into a 2.5 in, 4-mm I.D. glass tube, flame sealed at one end. This charcoal must be from the same batch as that used in obtaining the samples and can be obtained from unused charcoal tubes. The open end is capped with Parafilm. A known amount of hexane solution containing 94.5 mg/ml is injected directly into the charcoal with a microliter syringe, and the tube is capped with more Parafilm. When using an automatic sample injector, the sample injector vials, capped with Teflon-faced septa, may be used in place of the glass tubes.

The amount injected is equivalent to that present in a 20-liter air sample at the selected level. Six tubes at each of three levels (0.5X, 1X, and 2X of the standard) are prepared in this manner and allowed to stand for at least overnight to assure complete adsorption of the analyte onto the charcoal. These tubes are referred to as the samples. A parallel blank tube should be treated in the same manner except that no sample is added to it. The sample and blank tubes are desorbed and analyzed in exactly the same manner as the sampling tube described in Section 8.4.

Two or three standards are prepared by injecting the same volume of compound into 1.0 ml of carbon disulfide with the same syringe used in the preparation of the samples. These are analyzed with the samples.

The desorption efficiency (D.E.) equals the average weight in mg recovered from the tube divided by the weight in mg added to the tube, or

$$D.E. = \frac{\text{Average Weight recovered (mg)}}{\text{Weight added (mg)}}$$

The desorption efficiency is dependent on the amount of analyte collected on the charcoal. Plot the desorption efficiency versus weight of analyte found. This curve is used in Section 10.4 to correct for adsorption losses.

9. Calibration and Standards

It is convenient to express concentration of standards in terms of mg/1.0 ml carbon disulfide, because samples are desorbed in this amount of carbon disulfide. The density of the analyte is used to convert mg into microliters for easy measurement with a microliter syringe. A series of standards, varying in concentration over the range of interest, is prepared and analyzed under the same GC conditions and during the same time period as the unknown samples. Curves are established by plotting concentration in mg/1.0 ml versus peak area. Note: Since no internal standard is used in the method, standard solutions must be analyzed at the same time that the sample analysis is done. This will minimize the effect of known day-to-day variations and variations during the same day of the FID response.

10. Calculations

10.1 Read the weight, in mg, corresponding to each peak area from the standard curve. No volume corrections are needed, because the standard curve is based on mg/1.0 ml carbon disulfide and the volume of sample injected is identical to the volume of the standards injected.

10.2 Corrections for the blank must be made for each sample.

$$mg = mg\ sample - mg\ blank$$

where:

mg sample = mg found in front section of sample tube

mg blank = mg found in front section of blank tube

A similar procedure is followed for the backup sections.

10.3 Add the weights found in the front and backup sections to get the total weight in the sample.

10.4 Read the desorption efficiency from the curve (see Section 8.5.2) for the amount found in the front section. Divide the total weight by this desorption efficiency to obtain the corrected mg/sample.

$$\text{Corrected mg/sample} = \frac{\text{Total weight}}{\text{D.E.}}$$

10.5 The concentration of the analyte in the air sampled can be expressed in mg/cu m.

$$\text{mg/cu m} = \frac{\text{Corrected mg (Section 10.4)} \times 1000\ \text{(liter/cu m)}}{\text{Air volume sampled (liter)}}$$

10.6 Another method of expressing concentration is ppm.

$$\text{ppm} = \text{mg/cu m} \times \frac{24.45}{\text{M.W.}} \times \frac{760}{P} \times \frac{T + 273}{298}$$

where:

P	= pressure (mm Hg) of air sampled
T	= temperature (°C) of air sampled
24.45	= molar volume (liter/mole) at 25°C and 760 mm Hg
M.W.	= molecular weight (g/mole) of analyte
760	= standard pressure (mm Hg)
298	= standard temperature (°K)

11. References

11.1 White, L.D. et al. "A Convenient Optimized Method for the Analysis of Selected Solvent Vapors in the Industrial Atmosphere," Amer. Ind. Hyg. Assoc. J., 31: 225 (1970).

11.2 Documentation of NIOSH Validation Tests, NIOSH Contract No. CDC-99-74-45.

11.3 Final Report, NIOSH Contract HSM-99-71-31, "Personal Sampler Pump for Charcoal Tubes," September 15, 1972.

APPENDIX VIb

BISPHENOL A* AND DIGLYCIDYL ETHER OF BISPHENOL A**

Measurement Support Branch

Analytical Method

Analyte:	Bisphenol A (BPA), Diglycidyl Ether of Bisphenol A (DGEBA)	Method No.:	P&CAM 333
		Range:	0.441-1.77 mg/m^3 (BPA) 0.441-1.78 mg/m^3 (DGEBA)
Matrix:	Air		
		Precision:	0.018 (BPA) 0.027 (DGEBA) (analytical)
Procedure:	Filter collection, acetonitrile extraction, HPLC		
Date Issued:	8/29/80		
Date Revised:		Classification:	D (Operational)

1. Synopsis

A known volume of air is drawn through a glass fiber filter to collect BPA and DGEBA (as particulate) from the air. The exposed filter is then transferred to a screw cap vial and extracted with acetonitrile. An aliquot of this solution is injected into a high performance liquid chromatograph (HPLC). Peak areas are determined and compared with calibration curves derived from peak areas obtained from injections of standard solutions.

2. Working Range, Sensitivity and Detection Limit

2.1 The probable useful analytical range of this method is 0.4-511 µg BPA and 0.6-513 µg DGEBA per sample. However, the method has been evaluated for the 127-511 µg per sample or 0.551-1.77 mg/m^3. The air concentration range is based on a 288-L air sample. Samples with levels greater than 511 µg can be analyzed by increasing the volume of the extraction solvent or by decreasing the sensitivity setting of the HPLC detector or the quantity of the aliquot injected into the HPLC.

2.2 The detection limits for BPA and DGEBA by this method are 0.2 and 0.3 µg per filter respectively when the filter is extracted with 2-mL of acetonitrile and a 50-µL aliquot is injected into the HPLC.

3. Interferences

3.1 Any compound collected on the filter which has the same retention time as either BPA or DGEBA, under the operating conditions of this method, may interfere with the analysis and may be mistaken for the

*4,4'-Isopropylidenediphenol
**2,2-Bis[4-(2',3'-epoxypropoxy) phenyl]propane

analyte. By altering the composition of the mobile phase, a separation of BPA and DGEBA from the interfering material might be obtained.

3.2 If compounds other than BPA or DGEBA are known or suspected to be present in the atmosphere sampled, information regarding their identities should be transmitted with the samples to the laboratory.

3.3 If filter media other than the glass fiber filter are used for sample collection, materials may be extracted from the filter which will interfere with the analysis.

4. Precision and Accuracy

4.1 The relative standard deviation for the analytical method in the range of 127-511 µg /filter is 0.018 for BPA and 0.027 for DGEBA.

4.2 Bisphenol A recovery is 99.5% based on eighteen fortified glass fiber filters, six replicates at each of three loading levels: 127, 247, and 511 µg bisphenol A per sample.

4.3 DGEBA recovery is 99.3% based on eighteen fortified glass fiber filters, six replicates at each of three loading levels: 127, 250, and 513 µg DGEBA per sample.

4.4 The collection efficiencies for BPA and DGEBA as particulate by glass fiber filters have not been determined.

5. Advantages and Disadvantages

5.1 An advantage of the method is the specificity of the HPLC procedure in the absence of recalcitrant interferences.

5.2 A disadvantage related to the analysis of a large number of samples by this method is the relatively high cost of UV-grade acetonitrile.

6. Apparatus

6.1 Air Sampling Equipment

6.1.1 The sampler system consists of:

A filter holder for a 37-mm filter, Millipore or equivalent.

Glass fiber filter, 37-mm diameter, Gelman type A, or equivalent.

Cellulose backup pad, 37-mm diameter, Millipore or equivalent.

6.1.2 Personal Sampling Pump. A calibrated personal sampling pump whose flow can be determined to an accuracy of ± 5% at the recommended flow rate is needed. The pump must be calibrated with a representative filter holder and filter in the line.

6.2 HPLC and Accessories

6.2.1 High performance liquid chromatograph (HPLC) equipped with a variable wavelength ultraviolet detector.

6.2.2 A prepacked octadecyl silane reverse phase column, 0.63-cm i.d. by 30-cm long, Waters Associates μBondapack C_{18}, or equivalent.

6.2.3 Potentiometric strip chart recorder, 10-mV.

6.2.4 An electronic integrator if desired.

6.3 Glassware

6.3.1 A 100-μL glass syringe for injection of the samples.

6.3.2 Screw capped vials, 5-mL, with teflon-lined caps.

6.3.3 Pipettes and volumetric flasks of appropriate sizes for the preparation of standards.

6.3.4 Millipore all-glass filter apparatus, 47-mm, or equivalent.

6.4 Miscellaneous Apparatus

6.4.1 Analytical balance, Mettler H20T or equivalent.

6.4.2 Ultrasonic cleaner, Mettler Electronics Corp., or equivalent.

6.4.3 Swinney Filter, Millipore xx3001200 or equivalent.

7. Reagents

7.1 Acetonitrile, distilled in glass, UV-grade (Burdick and Jackson Laboratories, Muskegon, Mich., or equivalent).

7.2 4,4'-Isopropylidenediphenol (bisphenol A) for the preparation of standards.

7.3 2,2-Bis[4-(2',3'-epoxypropoxy)phenyl]propane, the diglycidyl ether of bisphenol A for preparation of standards.

7.4 Water, deionized, filtered (Milli-Q or equivalent).

8. Procedure

8.1 Cleaning of Equipment. Wash all glassware used for the analysis with detergent; rinse with distilled water and dry completely.

8.2 Collection of Air Samples

8.2.1 Assemble the filter in the three-piece filter cassette holder and close firmly to insure that the center ring seals the edge

of the filter. The glass fiber filter is held in place by a cellulose backup pad, and the filter holder is held together by plastic tape or a shrinkable cellulose band. If the middle piece of the filter holder does not fit snugly into the bottom piece of the filter holder, sample leakage will occur around the filter. A piece of flexible tubing is used to connect the filter holder to the pump.

8.2.2 Clip the cassette to the worker's lapel. Air being sampled should not be passed through any hose or tubing before entering the filter cassette.

8.2.3 A sample size of approximately 288 liters is recommended. Sample at a flow rate of 1.6 liters per minute. The flow rate should be known with an accuracy within ± 5%.

8.2.4 Turn the pump on and begin sample collection. Since it is possible for filters to become plugged by heavy particulate loading, by the presence of oil mists, or by other liquids in the air, the pump rotameter should be observed frequently, and the sampling should be terminated at any evidence of a problem.

8.2.5 Terminate sampling after the predetermined time and note sample flow rate, collection time, and ambient temperature and pressure. If pressure reading is not available, record the elevation.

8.2.6 Following collection, the sample cassette should be firmly sealed with the plugs in both the inlet and outlet ends.

8.2.7 Carefully record sample identity and all relevant sample data.

8.2.8 Blank. With each batch of ten samples, submit one filter from the same lot of filters which was used for sample collection and which is subjected to exactly the same procedures as the samples, except that no air is drawn through it. Label this as a blank.

8.2.9 Shipping. The filter cassettes should be shipped in a suitable container, designed to prevent damage in transit.

8.3 Analysis of Samples

8.3.1 Preparation of Samples. Remove the glass fiber filter from the sampler and place in a 5-mL screw cap vial. Add 2-mL of acetonitrile and cap the vial. Place the sample in an ultrasonic cleaner for 20 minutes (or shake for 5 minutes in a vortex mixer). Filter each sample through a 0.5-µm Millipore Fluoropore filter or equivalent, before injection. Blanks and spiked standards (See Section 9.2) are treated in the same manner.

8.3.2 Solvent Preparation. Acetonitrile should be filtered through a Millipore FHUP filter in the 47-mm all-glass filter apparatus. Water should be filtered using an HAWP filter (or equivalent).

8.3.3 Liquid Chromatography Conditions. The typical operating conditions for the liquid chromatograph are as follows:

Solvent A is 60% acetonitrile, 40% water (v/v).

Solvent B is 100% acetonitrile

Total solvent flow rate through the column is constant at 1.0 mL/min.

The UV-detector wavelength is set at 230-nm. The sensitivity setting is adjusted to give a full scale deflection for the highest standard.

A linear solvent gradient from 0% solvent B to 100% solvent B over a 30 minute period is run.

8.3.4 Injection of the Sample. Inject 50-µL of the sample using the 100-µL glass syringe. It may be necessary to decrease the volume of sample injected to keep the analyte peak on scale.

8.3.5 Measurement of Peak Area. Measure the area of the sample peak manually or with an electronic integrator.

9. Calibration and Standardization

9.1 Stock solutions of BPA and DGEBA are prepared by accurately weighing (approximately) 100-mg of each analyte in a 10-mL volumetric flask. The flask is diluted to the mark with acetonitrile. The stock solution is diluted 1:10 and 1:100 for use in preparing standards.

9.2 This method was evaluated, and the calibration curve found to be linear by spiking glass fiber filters over the following concentration range:

Low concentration	5-µL of 1:100 stock solution
High concentration	22-µL of 1:10 stock solution

The analyst should prepare standards by spiking six filters with the stock solutions as follows:

Amount	Dilution
5 - µL	1:100
10 - µL	1:100
20 - µL	1:100
5 - µL	1:10
10 - µL	1:10
20 - µL	1:10

9.3 Each spiked filter is extracted in 2-mL of acetonitrile along with the samples. The standards must be analyzed during the same time period as the field samples and under the same chromatographic conditions. This procedure will minimize the effect of day-to-day variations of the detector response or of the composition of the mobile phase.

9.4 A standard curve is generated by plotting the quantity of BPA and DGEBA in each standard versus the peak area obtained from the chromatogram or electronic integrator. Using the chromatographic conditions specified in 8.3.3, BPA elutes in about 4.5 minutes and DGEBA in about 9.0 minutes.

10. Calculations

10.1 The amount of BPA or DGEBA corresponding to the peak area in each particular sample is obtained from the standard curve. The quantity in ng is adjusted by a correction factor (to one mL) to account for the volume of each sample injected, thus giving the concentration of each sample in ng/mL. The total sample weight can be obtained by multiplying by the extraction volume which is 2 mL.

10.2 If a peak with the same retention time as BPA or DGEBA is present in the blank, it may not be necessary to subtract it from the samples. The standards are prepared in the same manner as the samples and will also contain the blank amount.

10.3 If desired, the concentration of BPA or DGEBA in the air sampled, C, may be expressed in $\mu g/m^3$

$$C = \frac{W}{V_s} \div 1000$$

where: V_s = volume (liter) of air sampled

W = weight (μg) of BPA or DGEBA in the sample

11. References

11.1 Szap, P., I. Kesse, and J. Klapp, The Analysis of Bisphenol A by High Pressure Liquid Chromatography. J. Liq. Chromatogr., 1, 89 (1978)

Richard Wade
UBTL Division of UURI
Contract No. 210-0078-0087

Barry R. Belinky, Project Officer
NIOSH,DPSE, MSB

APPENDIX VIc

ALIPHATIC AMINES IN AIR

Physical and Chemical Analysis Branch

Analytical Method

Analyte: Aliphatic Amines	**Method No.:** P&CAM 221
Matrix: Air	**Range:** 1 to 2400 mg/m³ in a 10-liter sample of air
Procedure: Adsorption on silica gel; elution with acid; GC analysis	**Precision (CV_T):** 0.03 for methylamine at 300 mg/m³
Date Issued: 1/29/76	**Classification:** E (Proposed)
Date Revised:	

1. **Principle of the Method**

1.1 A known volume of air is drawn through a tube containing silica gel to trap the aliphatic amines. The silica gel is transferred to glass-stoppered tubes and treated with sulfuric acid. A portion of the resulting acid solution is made alkaline with an excess of sodium hydroxide and an aliquot of the alkaline solution is analyzed by gas chromatography with a flame ionization detector.

1.2 The method may be used to determine a single aliphatic amine or to determine two or more amines in a single sample. The method has been applied to the following individual compounds:

Methylamine
Ethylamine
Dimethylamine
Isopropylamine
Butylamine
Diethylamine
Diisopropylamine
Triethylamine
Cyclohexylamine

2. **Range and Sensitivity**

2.1 The limit of detection of the method is 0.01 mg of amine (0.02 mg of methylamine) per sample when the analyte is desorbed from 150 mg of silica gel with 2 mℓ of sulfuric acid and a 3-μℓ aliquot of the alkaline mixture is analyzed. This limit corresponds approximately to 1 mg/m³ (2 mg/m³ for methylamine) in a 10-liter sample of air.

2.2 The upper limit is at least 24 mg of amine per sample. This amount of methylamine is retained by the 500-mg section of silica gel in the sorbent tube before breakthrough occurs. Larger amounts of other amines of higher molecular weight are retained. This limit for methylamine corresponds approximately to 2400 mg/m^3 in a 10-liter sample of air.

3. Interferences

3.1 The most common possible sampling interference is water vapor. With the sorbent tube described, 96 liters of air of 100% relative humidity can be sampled over an 8-hr period at 200 mℓ/min without displacement of the collected aliphatic amines by water vapor.

3.2 Any compound which has nearly the same retention time on the GC column as one of the aliphatic amines is an interferent. This type of interference can often be overcome by changing the GC operating conditions or by selecting another column. Retention time data on a single column, or even on a number of columns, cannot be considered as conclusive proof of chemical identity. It is important, therefore, that a sample of the bulk amine or mixture of amines be submitted at the same time as the sample tubes so that chemcial identification of possible interferents can be made. (The bulk sample must *not* be shipped in the same shipping container as the sample tubes.)

4. Accuracy and Precision

4.1 The volume of air sample can be measured to within ±1% if a pump with a calibrated volume indicator is used. Volumes calculated from initally set flow rates may be less accurate (± 5%) because of changes in flow rate during sampling.

4.2 The collection efficiency for aliphatic amines is esentially 100% under most conditions. as demonstrated by the negligible amount of amine collected in the backup sections of the sorbent tube.

4.3 The higher molecular weight amines and small amounts of all amines are incompletely desorbed. When a correction is made for desorption efficiency as described in Section 8.5, the accuracy approaches 100%.

4.4 Storage losses of 16-25% have been observed for primary amines on silica gel in sealed tubes stored for 1 month. Storage losses of 6-7% have been observed for secondary amines over 1 month. Triethylamine was stable for this period. Refrigeration of samples decreases such losses and is recommended if analysis is not to be performed within a few days.

4.5 The precision of the analysis is dependent upon the precision and sensitivity of the technique used to quantitate the gas chromatographic peaks of samples and standards. Electronic digital integrators with baseline correction capabilities will maximize analytical precision, particularly at lower concentrations. For the lower concentrations (0.01 to 0.2 mg/sample) the analytical precision may be ±20%; at higher concentrations it approaches ±3%.

4.6 A coefficient of variation of 0.03 has been determined for the analysis of 10 samples of 1.2 mg of methylamine collected from 4 liters of air (300 mg/m^3) with a personal sampling pump. The recovery was 99%.

5. Advantages and Disadvantages

5.1 The sampling method uses a small, portable device involving no liquids. The sorbent tube can be used for at least 8 hr to measure an average workday concentration, or for only 15 min to measure an excursion concentration. Desorption of the sample and preparation for analysis are simple. The analysis is accomplished by a rapid instrumental method.

5.2 Most analytical interferences can be eliminated by altering the GC conditions.

5.3 Several aliphatic amines can be collected and determined simultaneously. This is especially useful when the identity and composition of the amine vapors are not known.

5.4 The major disadvantage of the method is the necessity for measuring desorption efficiencies. When the desorption is less than complete, as for higher molecular weight amines, the effect of the amount of compound absorbed must also be determined.

6. Apparatus

6.1 Air Sampling Equipment

6.1.1 Sorbent tubes. The sorbent tubes consist of Pyrex glass tubes 125 mm long and 8 mm i.d., packed with three separate sections of 45/60-mesh activated silica gel. The weights of the three sections of silica gel are, in order, 600, 150, and 150 mg; these tubes are designed for sample flow in either direction. Plugs of 100-mesh stainless steel screen are used to contain the silica gel sections. These plugs of negligible pressure drop are prepared from 7-mm discs of screen held in place by Teflon rings. Pieces of Pyrex tubing 12 mm long and 7 mm in o.d. are located between the sorbent sections to inhibit migration of the amines. The ends of the tubes are flamesealed after packing to prevent contamination before use for sampling. The pressure drop across the tubes does not exceed 6 cm of water at a flow rate of 200 mℓ/min. The silica gel should be the equivalent of Silica Gel D-08, Chromatographic Grade, Activated and Fines Free, 45/60-mesh, as supplied by Applied Science Laboratories, Inc., State College, Pa. Polyethylene caps should be provided to seal the tubes after sampling has been completed.

6.1.2 **Personal Sampling Pump.** The personal sampling pump should be capable of operation at a constant flow rate or 200 mℓ/min for up to 8 hr. A sample volume indicator is desirable. The pump should be calibrated with a representative sorbent tube in the line. A wet or dry test meter or a glass rotameter capable of measuring a flow rate of 200 mℓ/min to within ±5% may be used in the calibration.

6.2 Gas chromatograph with a flame ionization detector and linear temperature programming.

6.3 A 1.8-m by 4-mm silanized glass column packed with 60/80-mesh Chromosorb 103 (Johns-Manville), or equivalent.

6.4 A 15-cm by 4-mm silanized glass precolumn packed with 10 cm of 8/20-mesh Ascarite (Arthur H. Thomas Company), or equivalent, and fitted into the injection port. The precolumn should be replaced when the precision of the analysis becomes poor.

6.5 Recorder with an electronic digital integrator.

6.6 Glass-stoppered test tubes or flasks.

6.7 Glass syringes, 10 μℓ.

6.8 Pipettes and volumetric flasks for preparation of standard solutions.

7. **Reagents**

7.1 Sulfuric acid, 1.0 *N*.

7.2 Sodium hydroxide, 1.1 *N*.

7.3 Aliphatic amines, highest purity available (for use as standards).

7.4 Helium, Bureau of Mines Grade A.

7.5 Hydrogen, prepurified.

7.6 Air, compressed and filtered.

8. **Procedure**

8.1 **Cleaning of Equipment.** Wash all glassware with detergent solution and rinse with tap and distilled water. Dry in an oven.

8.2 **Collection and Shipping of Samples**

8.2.1 Immediately before beginning the collection of a sample, break each end of the sorbent tube so as to provide openings at least half the inside diameter of the tube.

8.2.2 Choose the direction desired for sample flow, mark the inlet end of the tube with a permanent marker, and attach the other end to the sampling pump. For low concentrations of amines, low humidity conditions, or short sampling periods, pump the sample air through the 150-mg sorbent section first; for high concentrations, high humidity, or long sampling periods, pump the sample air through the 600-mg sorbent section first. Sample air must not pass through any hose or tubing before entering the sorbent tube.

8.2.3 With the sorbent tube in a vertical position, sample the air at 200 mℓ/min for the desired period of time (0.25 to 8 hr). The flow rate and sampling time, or the volume, must be measured as accurately as possible. The temperature and pressure of the air being sampled should be measured and recorded.

8.2.4 Immediately after sampling is completed, cap the sorbent tubes with the polyethylene caps provided. Rubber caps must not be used.

8.2.5 One tube should be handled in the same manner as the sample tubes (break, seal, and ship) except that no air is pumped through it. Label this tube as a blank.

8.2.6 Pack the tubes tightly before shipping to minimize breakage in transit.

8.2.7 After the sample is collected the tubes should not be subjected to extremes of high temperature or low pressure. Refrigeration will reduce sample loss.

8.3 **Analysis of Samples**

8.3.1 **Preparation of Samples.** Remove and discard the stainless steel plugs and glass spacers and transfer each section of silica gel to a separate glass-stoppered test tube or flask. Label the samples and analyze each section separately.

8.3.2 **Desorption.** Desorb the amines from the silica gel by adding 2 mℓ of 1.0 *N* sulfuric acid to the 150-mg sections and 8 mℓ to the 600-mg section. Shake the sample mixtures occasionally over a period of 1 hr. Tests have indicated that desorption reaches a maximum in an hour.

8.3.3 **Neutralization.** Transfer a 0.5-mℓ aliquot to another container and add 0.5 mℓ of 1.1 *N* sodium hydroxide to make the solution alkaline and regenerate the free amines. An aliquot of this solution is then analyzed by gas chromatography.

8.3.4 **Gas Chromatographic Conditions.** Typical operating conditions for the gas chromatograph are as follows:

Helium carrier gas flow rate, 120 mℓ/min.

Hydrogen gas flow rate to detector, 40 mℓ/min.

Air flow rate to detector, 540 mℓ/min.

Injection port temperature, 160°C.

Detector temperature, 190°C.

Column temperature, 115 to 180°C at 10°C/min; hold for 10 min.

For a sample containing only one amine or a sample containing two closely eluting amines, the column temperature may be kept isothermal at an appropriate temperature.

8.3.5 **Injection of Sample.** To eliminate difficulties arising from blowback or distillation within the syringe, use the solvent flush injection technique. Flush the 10-μℓ syringe several times with distilled water to set the barrel and plunger. Draw in 3 μℓ of water. With the needle removed from the water, pull the plunger back about 0.2 μℓ to draw in a pocket of air. Then immerse the needle in the sample solution and withdraw a 3-μℓ aliquot, taking into consideration the volume in the needle. After the needle is removed from the sample solution and prior to injection, pull the plunger back a short distance to minimize evaporation at the tip of the needle. Inject duplicate 3-μℓ aliquots of each sample and standard.

8.3.6 **Measurement of Peak Area.** Measure the area of each amine peak with an electronic digital integrator or other suitable means of area measurement. Estimate the amount of each individual amine from calibration curves prepared as described in Section 9.

8.4 Determination of Desorption Efficiency

8.4.1 **Importance of Determination.** Desorption efficiency for a particular compound can vary from one lot of silica gel to another, and also from one laboratory to another. Therefore, it is necessary to determine at least once the desorption efficiency for each amine with each lot of silica gel used. Among the aliphatic amines listed in Section 1.2 desorption efficiency decreases with increasing molecular weight. Desorption efficiency increases with increasing ratio of sulfuric acid to silica gel; however, an increase in this ratio results in a reduction in analytical sensitivity. A compromise ratio of 75 mg of silica gel per milliliter of sulfuric acid is recommended. Desorption efficiency may also vary with the amount of amine present on the silica gel. Measurements of efficiency should, therefore, be made for at least two amounts within the normal range of sample size.

8.4.2 **Procedure for Determination of Desorption Efficiency.** Place 150 mg of silica gel in a 2-mℓ glass-stoppered tube. The silica gel must be from the same lot as that used in collecting the sample; it can be obtained from unused sorbent tubes. With a microliter syringe, inject a known amount of the amine, either pure or in water solution, directly onto the silica gel. Close the tube with the glass stopper and allow it to stand at least overnight to insure complete adsorption of the amine. Prepare at least three tubes for each of at least two different amounts of amine. These tubes are referred to as samples. Prepare a blank in the same manner, omitting the amine. Analyze the samples and blank as described in Section 8.3. Also analyze three standards prepared by adding identical amounts of the amine to 2.0 mℓ of 0.1 *N* sulfuric acid. Determine the concentrations of the amine in the blank, samples, and standards using calibration curves prepared as described in Section 9. The desorption efficiency is calculated by dividing the concentration of amine found in the sample by the concentration obtained for the corresponding standard.

9. Standards and Calibration

9.1 For accuracy in the preparation of standards, it is recommended that an initial standard be prepared in a relatively large volume and at a high concentration. Aliquots of this standard can then be diluted to prepare other standards. Prepare the initial standard by pipetting an appropriate volume of amine into a 100-mℓ volumetric flask and adding distilled water to the mark. Check the concentration of this solution by titrating with standard sulfuric acid. Make the first dilution by adding an equal volume of 2.0 *N* sulfuric acid to an aliquot of the initial standard. Make additional dilutions with 1.0 *N* sulfuric acid so that the final concentration of sulfuric acid will be the same in standards and samples.

9.2 For example, to prepare butylamine standards add 1.0 mℓ of butylamine to a 100-mℓ volumetric flask and dilute to the mark with water. The concentration of this initial standard is 7.39 mg/mℓ or 0.101 *M*. This concentration can be easily checked by titration with 0.100 *N* sulfuric acid. Dilute a 25-mℓ aliquot of the initial standard with 25 mℓ of 2.0 *N* sulfuric acid to give a second standard of 3.695 mg/mℓ in 1.0 *N* sulfuric acid. Dilute 1.0 mℓ of this second standard to 25 mℓ with 1.0 *N* sulfuric acid to give a concentration of 0.148 mg/mℓ. This concentration in 1.0 *N* sulfuric acid is comparable to that obtained by sampling butylamine in air at its TLV concentration (15 mg/m^3) on 600 mg of silica gel for 6 hr at 200 mℓ/min and desorbing into 8 mℓ of 1.0 *N* sulfuric acid; if the desorption efficiency is 100%, the resulting concentration of butylamine is 0.135 mg/mℓ. Various volumes of the second standard (3.695 mg/mℓ) should be diluted to 25 mℓ to give a series of working standards covering the range of interest.

9.3 The standards prepared as described above should be analyzed under the same gas chromatographic conditions and during the same time period as the unknown samples. This will minimize the effect of day-to-day variations in the response of the flame ionization detector.

9.4 A calibration curve is prepared for each amine by plotting average peak area against concentration of the standard solution in mg/mℓ (mg of amine per mℓ of 1.0 *N* sulfuric acid).

10. Calculations

10.1 From the calibration curve read the concentration of the amine corresponding to the average peak height measured. Multiply this concentration value by the volume of 1.0 *N* sulfuric acid used to desorb the amine from the silica gel (8 mℓ for 600 mg of silica gel, or 2 mℓ for 150 mg). The result is the weight of amine (in mg) in the silica gel section. Correct each value for the amount of amine found in the corresponding blank. Also, correct each value for the desorption efficiency as determined in Section 8.4.2. Add the corrected amounts of amine found in the front and backup sections of the same sample tube to obtain the total weight of amine in the air sample.

10.2 The concentration of the amine in air may be expressed in mg/m^3:

$$\text{mg/m}^3 = \frac{\text{corrected weight (mg)}}{\text{volume of air sampled (ℓ)}} \times 1000\ \text{ℓ/m}^3$$

10.3 The concentration may also be expressed in terms of parts per million (ppm) by volume:

$$ppm = mg/m^3 \times \frac{24.45}{M.W.} \times \frac{760}{P} \times \frac{T+273}{298}$$

where: 24.45 = molar volume (ℓ/mole) at 25° C and 760 mmHg.

M.W. = molecular weight.

P = pressure (mmHg) of air sampled.

T = temperature (°C) of air sampled.

11. References

11.1 Campbell, Evan E., G.O. Wood, and R.G. Anderson, "Development of Air Sampling Techniques," Los Alamos Scientific Laboratory, Progress Reports LA-5634-PR (June 1974), LA-5973-PR (July 1975), and LA-6057-PR (September 1975).

11.2 Andre, C.E., and A.R. Mosier, "Precolumn Inlet System for the Gas Chromatographic Analysis of Trace Quantities of Short-Chain Aliphatic Amines," Anal. Chem., 45, 1971 (1973).

11.3 Wood, G. O., and R. G. Anderson, "Development of Air Monitoring Techniques Using Solid Sorbents," Los Alamos Scientific Laboratory, Progress Reports LA-6216-PR (February 1976) and LA-6513-PR (September 1976).

APPENDIX VId

ETHYLENEDIAMINE AND DIETHYLENETRIAMINE

Measurements Research Branch

Analytical Method

Analytes:	Ethylenediamine (1,2-Diaminoethane) Diethylenetriamine (bis(2-aminoethyl)amine)	Method No:	P&CAM 276
Matrix:	Air	Range:	See Paragraph 2
Procedure:	Adsorption on silica gel, elution with methanolic acid, derivatization with benzaldehyde, GC analysis	Precision:	2-8% (Analytical)
Date Issued:	8/1/78		
Date Revised:		Classification:	E (Proposed)

1. Synopsis

A known volume of air is drawn through a tube containing silica gel to trap vapors of the compounds. Concentrated HCl is added to stabilize amines collected. The sorbent sections are transferred to glass vials and treated with methanol solution. An aliquot is alkalinized with sodium hydroxide. Benzaldehyde is added to form dibenzylidene derivatives. The solution is analyzed by gas chromatography with flame ionization detection.

2. Working Range, Sensitivity, and Detection Limit

The ranges of the method for the two analytes are at least

Ethylenediamine	0.2 - 7 mg/sample
Diethylenetriamine	0.2 - 9 mg/sample

Data relating to the lower ends of the range are given in Paragraphs 4.2, 4.3, and 4.6. The upper limits are determined by the capacities of the first section of the sampling tube used to collect the sample. Amounts of individual compounds retained on 150 mg of a 42/60-mesh silica gel in 6-mm-i.d. sampling tubes at 1 L/min sampling flow rate were found to be those given above as the upper limits.

3. Interferences

3.1 Water vapor does not significantly affect collection efficiency.

3.2 Large amounts of ammonia or primary amines will reduce the amount of benzaldehyde available for reaction with the analytes. Such interferences should be compensated for by adding additional benzaldehyde.

3.3 Any compound which has nearly the same retention time on the GC column as one of the analytes is an interference. Retention time data on a single GC column cannot be considered as proof of chemical identity. The presence and identity of possible interfering substances may be determined by the analysis of bulk samples from the process or environment.

4. Precision and Accuracy

4.1 The volume of air sampled can be measured to within $\pm$ 2% if a pump with a calibrated volume indicator and an adequate battery is used. Volumes calculated from initially set flow rates may be less accurate ($\pm$ 5-10%) unless changes in flow rate are manually or electronically monitored and compensated.

4.2 Precision (relative standard deviation) of replicate GC analyses of standards was measured to be:

Ethylenediamine	5% at 0.05 mg/mL eluent
Diethylenetriamine	8% at 0.09 mg/mL eluent

These levels correspond to sample sizes of 0.1 mg and 0.2 mg, respectively. At the upper limits of the method analytical precision becomes 2% relative standard deviation or better.

4.3 The precision (relative standard deviation) of the method based on analyses of replicate 0.1 mg samples injected by syringe into silica gel sections or into 2 mL of eluent was 14% for both compounds.

4.4 The precision of the analysis is dependent upon the precision and sensitivity of the technique used to quantitate the GC peaks of samples and standards. An electronic digital integrator with baseline correction capability is best for this purpose.

4.5 Collection efficiency is 100% until breakthrough of the sampling tube bed occurs (see Section 2).

4.6 Desorption efficiencies for both compounds based on analyses of replicate 0.1 mg samples on silica gel and standards in 2 mL eluent were found to be 102% with a relative standard deviation of 20%. Measurements at higher sample levels have given desorption efficiencies consistently in the range 90-100% with better precision.

4.7 This method has given quantitative results equivalent to an independent method involving adsorption of ethylenediamine vapors in water in a bubbler and titration with standard acid. Using each method six 0.030-m^3 vapor-in-nitrogen samples were taken at 1 L/min. The following sample amounts and relative standard deviations in parentheses were determined:

Tube and chromatography: 3.30mg (4%)

Bubbler and titration: 3.42mg (2%)

5. Advantages and Disadvantages

5.1 The method uses a small, portable sampling device involving no liquids. This is an advantage for sampling air in a worker's breathing zone without interfering with normal work activities. Transportation to the analytical laboratory is simplified with the solid sorbent tube.

5.2 The sorbent tube has a high capacity even at high relative humidities. It can be used for at least eight hours to measure a workday average concentration, or for shorter times to measure excursion concentrations.

5.3 Desorption and preparation of samples for analysis involve simple procedures and equipment.

5.4 Several amines can be collected and determined simultaneously. The GC analysis distinguishes which are present and at what individual concentrations they occur. Interferences by other amines are much less likely than in colorimetric or titrimetric methods.

5.5 A major disadvantage is the tendency of amines to oxidize while adsorbed on surfaces exposed to air. This is overcome by addition of concentrated hydrochloric acid to the sorbent sections soon after sampling.

6. Apparatus

6.1 Air Sampling Equipment

6.1.1 Sorbent. The silica gel used should be the equivalent of Silica Gel D-08, chromatographic grade, activated and fines free, 42/60 mesh, as produced by Coast Engineering Laboratories and sold by Applied Science Laboratories, Inc. of State College, Pennsylvania.

6.1.2 Sampling Tubes. Glass tubes 7-cm-long and 6-mm-i.d., tapered and flame sealed at one end, are packed with two 150-mg sections of silica gel. Glass wool plugs are used to separate and enclose the sections. The second end is flame sealed to prevent contamination during storage

prior to use. Polyethylene caps are used to seal tubes after sampling is completed.

NOTE: Sampling tubes constructed with metal parts or urethane foam plugs should not be used. Concentrated hydrochloric acid will react with these materials.

6.1.3 Personal Sampling Pump. Battery-operated pumps are required, capable of operation at 0.2 L/min for up to eight hours or at 1.0 L/min for up to two hours with a sampling tube in line. The pump is to be calibrated with a representative sorbent tube in line. A wet or dry test meter or bubble meter capable of measuring a flow rate of 0.2 L/min and/or 1.0 L/min to within $\pm$ 2% may be used in setting the pump flow.

6.2 Gas chromatograph with a flame ionization detector. Temperature programming capability is necessary to determine more than one compound simultaneously.

6.3 GC column, 0.6-m x 4-mm i.d. glass, silanized and packed with 10% (by weight) silicone SE-30 on 80/100-mesh supelcoport or equivalent support.

6.4 Strip chart recorder compatible with the GC. An electronic digital integrator is desirable.

6.5 Test tubes or glass vials, 2-mL, sealed by a septum.

6.6 Syringes, 10-µL.

6.7 Syringe for dispensing concentrated HCl, 50-µL, with glass barrel, fluorocarbon-tipped plunger, and inert (platinum or fluorocarbon) needle.

6.8 Pipettes, 0.5-mL and 2-mL.

6.9 Volumetric flasks, 10-mL.

6.10 File and Forceps.

7. Reagents

All chemicals must be analytical reagent grade.

7.1 Ethylenediamine.

7.2 Diethylenetriamine.

7.3 Water, doubly distilled and aldehyde-free. Deionized water should not be used as it may contain formaldehyde and other impurities leached from the ion-exchange resins.

7.4 Concentrated hydrochloric acid (38%, 12 M).

7.5 Benzaldehyde.

7.6 Eluent solution, 4:1 methanol-water (by volume).

7.7 Alkalinizing solution, 0.20 N NaOH in 4:1 methanol-water (by volume).

7.8 Helium, Bureau of Mines Grade A.

7.9 Hydrogen, prepurified.

7.10 Air, compressed and filtered.

8. Procedure

8.1 Cleaning of Equipment. All glassware is washed with detergent solution, rinsed with tap water and distilled water, and dried in an oven.

8.2 Collection and Shipping of Samples

8.2.1 Immediately before beginning the collection of a sample, break each end of the sorbent tube so as to provide openings at least 2 mm in diameter.

8.2.2 Attach the tubing from the sampling pump to the backup end of the sampling tube. Sampled air must not pass through any hose or tubing before entering the sorbent tube.

8.2.3 With the sorbent tube in a vertical position as much as is practical, sample the air at 1.0 L/min for 15 min-2 hours or at 0.2 L/min for 2-8 hours. Intermediate flow rates and other sampling periods may be used, as appropriate.

8.2.4 Immediately after sampling is completed, add 20 µL of concentrated HCl to each section of silica gel in the tube. Use a 50-µL glass syringe with fluorocarbon-tipped plunger and inert needle, so that the acid does not contact and react with stainless steel. The silica gel will turn yellow upon addition of the acid due to iron impurities in the silica gel.

8.2.5 Seal the sorbent tubes with polyethylene caps.

8.2.6 Obtain a blank sample by handling one tube in the same manner as the sample tubes (break, add acid, seal, and ship) except that no air is pumped through it.

8.2.7 For shipping to the laboratory, pack the tubes tightly to minimize chances of breakage during transit. Tubes should not be subjected to extremes of high temperature or low pressure.

8.3 Analysis of Samples

8.3.1 Preparation of Samples. Score each tube with a file 5 mm in front of the glass wool plug that precedes the first sorbent section and break the tube there. Transfer this plug and the initial section to a 2-mL test tube or glass vial that can be septum sealed. Likewise, transfer the second plug and sorbent section to another test tube. Label each appropriately for separate analysis.

8.3.2 Desorption. Add 2 mL of eluent solution to each sorbent section. Seal the samples. Shake the mixtures occasionally over a period of two hours. Tests have shown that complete desorption occurs within two hours and samples are stable for at least a day.

8.3.3 Preparation and Reaction. Transfer a 0.50-mL aliquot of each eluate to another test tube or vial. Add 0.50 mL of alkalinizing solution and mix thoroughly. Verify the basicity of the solution with litmus paper. Add 10-µL of benzaldehyde to the basic solution, mix thoroughly, and allow at least 20 min for reaction.

8.3.4 Gas Chromatograph Conditions

Helium gas flow rate, 30 mL/min.
Injection port temperature, 200 °C.
Detector temperature, 250 °C.
Column temperature, 200 °C for
1,2-(dibenzylideneamino)ethane and
235 °C for 2,2'-(dibenzylideneamino)diethylamine.

Under these conditions, retention times are 300 sec for 1,2-(dibenzylideneamino)ethane and 345 sec for 2,2'-(dibenzylideneamino)diethylamine.

8.3.5 Injection of Sample. Inject and analyze 3-µL aliquots of each sample and standard. To eliminate difficulties arising from blowback or distillation within the 10-µL syringe, use a solvent flush technique.

8.3.6 GC Peak Measurement. Determine the areas of the peaks of the compounds of interest from analyses of samples and standards.

8.4 Determination of Desorption Efficiency

8.4.1 Importance. Desorption efficiency for a particular compound can vary from one lot of silica gel to another and from one laboratory to another. Also, for a given lot of silica gel the desorption efficiency may vary with the amount of material adsorbed during sampling. Therefore, it is necessary to determine at least once the desorption

efficiency for each analyte with each lot of silica gel used for at least two levels within the normal range of samples size. If the desorption efficiencies are significantly different from quantitative recovery, they should be used to correct the measured weight of analyte as described in Section 10.2 below.

8.4.2 Procedure. Place 150 mg of silica gel in a 2-mL glass-stoppered tube. The silica gel must be from the same lot as that used in collecting the sample; it can be obtained from unused sorbent tubes. With a microliter syringe, inject a known amount of amine, either pure or in water solution, directly onto the silica gel. Also inject 20 µL of concentrated HCl. Close the tube with the glass stopper and allow it to stand overnight to insure complete adsorption of the amine. Prepare at least three tubes for each at two different levels. These tubes are referred to as samples. Prepare a blank in the same manner, omitting the amine. Analyze the samples and blank as described in Section 8.3. Also analyze three standards prepared by adding identical amounts of the amine and 20 µL of concentrated HCl to 2.0 mL of eluent solution. Determine the concentrations of the analytes in the blank, samples, and standards using calibration curves prepared as described in Section 9. The desorption efficiency is calculated by dividing the concentration of amine found in the sample by the concentration obtained for the corresponding standard.

9. Calibration and Standardization

9.1 Preparation of a Stock Solution. Calculate for each compound i the volume V_i (µL) of pure liquid required for preparation of 10 mL of a stock solution, 10 µL of which contains amounts of analytes equal to those collected from volume of air V_s at concentrations X_i.

$$V_i = \frac{X_i \times V_s}{d_i} = 1000$$

Where:

X_i - the standard concentration limit, or the anticipated average concentration, (mg/m^3) of compound i in air.

V_s - volume (m^3) of air sampled.

d_i - density (mg/µL) of a pure compound i.

1000 - aliquot factor.

Add the calculated volumes of each compound to a 10-mL volumetric flask and dilute to the mark with 4:1 methanol-water. Neutral solutions of amines are subject to oxidation and should be prepared fresh when needed.

9.2 Preparation of Calibration Standards. Add 2.5 µL, 5 µL, 10 µL 15 µL and 20 µL of the prepared standard to reaction tubes containing 2 mL eluent solution and 40 µL concentrated hydrochloric acid. Use a 10-µL syringe to inject through septum seals. Shake these tubes. These standards correspond to 0.25, 0.5, 1, 1.5, and 2 times X_i in V_s, respectively. Other standards may be similarly prepared, if desired.

9.3 React and analyze standards with samples according to Section 8.3.

9.4 Prepare a calibration curve for each amine by plotting peak areas obtained from the analyses of standards against nominal amount (mg) in the calibration standards.

10. Calculations

10.1 Read the weights (mg) of each compound corresponding to each peak area from the appropriate calibration curve. Correct each value for the weight found in a blank, if any. Add the weights found in the front and backup sections of the sample tube to obtain the total weight of compound in the air volume sampled.

10.2 Divide the total weight by the desorption efficiency to obtain the corrected sample weight.

10.3 Determine the volumes (m^3) of air sampled at ambient conditions based on the appropriate information, such as flow rate (L/min) multiplied by sampling time (min) and 10^{-3} m^3/L. If a pump using a rotameter for flow rate control was used for sample collection, a pressure and temperature correction must be made for the indicated flow rate. The expression for this correction is:

$$V_s = 10^{-3} \times f \times t \sqrt{\frac{P_1}{P_2} \times \frac{T_2}{T_1}} .$$

where:

f - sample flow rate (L/min)
t - sampling time (min)
P_1 - pressure during calibration of sampling pump (torr)
P_2 - Pressure of air sampled (torr)
T_1 - temperature during calibration of sampling pump (°K)
T_2 - temperature of air sampled (°K)

10.4 Divide the total corrected weight (mg) of each compound by V_s (m^3) to obtain the concentration of the compound in the air sampled (mg/m^3).

11. References

11.1 G. O. Wood, R. G. Anderson, and J. W. Nickols, "Sampling and Analysis of Aminoethanols in Air," Report LA-UR-77-1398 (1977), Industrial Hygiene Group, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. (Presented at the 1977 American Industrial Hygiene Conference, May 1977, New Orleans).

11.2 G. O. Wood and J. W. Nickols, "Development of Air-Monitoring Techniques Using Solid Sorbents,October 1, 1976 - December 31, 1977," Progress Report LA-7295 -PR (1978), Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Also available from the National Technical Information Services, Springfield, VA.

Gerry Odell Wood
Industrial Hygiene Group
Los Alamos Scientific Laboratory
NIOSH-IA-77-12

APPENDIX VII

SAMPLE MATERIAL SAFETY DATA SHEETS

PLASTICS & ADDITIVES DIVISION
CIBA-GEIGY Corporation
Ardsley, New York 10502
(914) 478-3137

CIBA—GEIGY

SAFETY DATA SHEET

The information and recommendations contained herein are based upon data believed to be correct. However, no guarantee or warranty of any kind expressed or implied is made with respect to the information contained herein.

SECTION I.

TRADE NAME	PRODUCT TYPE
ARALDITE 7072	Solid Epoxy Resin
CHEMICAL FAMILY: Epoxides	

SECTION II. HAZARDOUS INGREDIENTS

INGREDIENT	%	TLV (UNITS)	INGREDIENT	%	TLV (UNITS)

SECTION III. PHYSICAL DATA

BOILING POINT (°F.)		SOLUBILITY IN WATER	Insoluble
MELTING POINT (°F.)	167-185	SPECIFIC GRAVITY (H_2O=1) @ 77°F	1.19
VAPOR PRESSURE (mm Hg.)		PERCENT VOLATILE BY VOLUME (%)	
VAPOR DENSITY (AIR=1)		EVAPORATION RATE (=1)	
APPEARANCE AND ODOR	Clear amber-colored solid.		

SECTION IV. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (°F.) (Method Used)	FLAMMABLE LIMITS IN AIR	LEL	UEL
>200°F Pensky-Martens Closed Cup			

EXTINGUISHING MEDIA: Carbon dioxide, dry chemical, foam.

SPECIAL FIRE FIGHTING PROCEDURES: None.

UNUSUAL FIRE AND EXPLOSION HAZARDS: None.

SECTION V. REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID
	STABLE	X	

INCOMPATIBILITY (Materials to Avoid): Strong oxidizing agents.

HAZARDOUS DECOMPOSITION PRODUCTS: Carbon monoxide and/or carbon dioxide.

HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	

D-1.614 7/75

SECTION VI. HEALTH HAZARD DATA

ORAL: LD_{50}	(rat) 30,000 mg/kg
DERMAL: LD_{50}	
IRRITATION: SKIN	Not an irritant. SPI CLASS 1
EYE	
SENSITIZATION	Not a sensitizer.
THRESHOLD LIMIT VALUE	
RESPIRATORY	
EFFECTS OF OVEREXPOSURE	None expected.
EMERGENCY & FIRST AID PROCEDURES:	
INHALATION	Remove to fresh air.
INGESTION	If conscious give water or milk and induce vomiting.
SKIN	Wash with soap and water.
EYES	Flush with plenty of water.
OTHER	

SECTION VII. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Sweep or scrape into container for vapor disposal.

Flush contaminated areas with water.

WASTE DISPOSAL METHOD

Incineration or landfill under approved conditions.

SECTION VIII. SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify Type)	Dust respirator. NIOSH approved.
PROTECTIVE CLOTHING	Impervious gloves.
EYE PROTECTION	Splash-proof goggles.
VENTILATION	General mechanical ventilation and local exhaust.

SECTION IX. SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING, STORING ETC.

CAUTION:

In accord with good industrial practice, handle with due care and avoid unnecessary personal contact.

For Manufacturing Use Only.

DATE: _____ SIGNATURE: _____

PLASTICS & ADDITIVES DIVISION
CIBA-GEIGY Corporation
Ardsley, New York 10502
(914) 478-3137

CIBA—GEIGY

SAFETY DATA SHEET

The information and recommendations contained herein are based upon data believed to be correct. However, no guarantee or warranty of any kind expressed or implied is made with respect to the information contained herein.

SECTION I

TRADE NAME: ARALDITE 6010	PRODUCT TYPE: Liquid Epoxy Resin
CHEMICAL FAMILY: Epoxides	

SECTION II. HAZARDOUS INGREDIENTS

INGREDIENT	%	TLV (UNITS)	INGREDIENT	%	TLV (UNITS)

SECTION III. PHYSICAL DATA

BOILING POINT (°F.)		SOLUBILITY IN WATER	Insoluble
MELTING POINT (°F.)		SPECIFIC GRAVITY (H_2O=1) @ 77°F	1.16
VAPOR PRESSURE (mm Hg.)		PERCENT VOLATILE BY VOLUME (%)	
VAPOR DENSITY (AIR=1)		EVAPORATION RATE (=1)	
APPEARANCE AND ODOR: Clear colorless to light-colored liquid			

SECTION IV. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (°F.) (Method Used): 490 (Pensky-Martens Closed Cup)	FLAMMABLE LIMITS IN AIR	LEL	UEL

EXTINGUISHING MEDIA: Carbon dioxide, foam, dry chemical, water spray.

SPECIAL FIRE FIGHTING PROCEDURES: Use self-contained breathing apparatus.

UNUSUAL FIRE AND EXPLOSION HAZARDS: No unusual hazards.

SECTION V. REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID: Storage at elevated temperatures over long periods of time degrades the resin.
	STABLE	X	
INCOMPATIBILITY (Materials to Avoid): Strong oxidizing agents.			
HAZARDOUS DECOMPOSITION PRODUCTS: Carbon monoxide and/or carbon dioxide.			
HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	

D-11614 /79

SECTION VI. HEALTH HAZARD DATA

ORAL: LD_{50} (rat)	13,300 mg/kg
DERMAL: LD_{50} (rabbit)	>6,000 mg/kg
IRRITATION: SKIN (rabbit)	Mild. SPI CLASS. 2
EYE (rabbit)	Mild.
SENSITIZATION	Moderate sensitizer.
THRESHOLD LIMIT VALUE	
RESPIRATORY	May cause sensitization.
EFFECTS OF OVEREXPOSURE	Possible irritation and sensitization.
EMERGENCY & FIRST AID PROCEDURES:	Call a physician.
INHALATION	Remove to fresh air. Oxygen & artificial respiration, if necessary.
INGESTION	If conscious, give water or milk. Induce vomiting.
SKIN	Remove contaminated clothing. Wash with soap and water.
EYES	Flush with water for at least 15 minutes.
OTHER	

SECTION VII. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Remove all sources of ignition.
Absorb on combustible material for proper disposal.
Flush contaminated areas with water.

WASTE DISPOSAL METHOD

Incineration in accordance with local pollution regulation and ordinance.

SECTION VIII. SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify Type)	NIOSH approved organic vapor respirator recommended.
PROTECTIVE CLOTHING	Impervious gloves.
EYE PROTECTION	Splash-proof goggles.
VENTILATION	General mechanical ventilation and local exhaust.

SECTION IX. SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING, STORING ETC.

WARNING! Causes Irritation
May Cause Sensitization

Avoid contact with eyes, skin and clothing.

Wash thoroughly after handling.

First Aid: In case of contact,

Eyes - Immediately flush eyes with plenty of water for at least 15 minutes. Call a physician.

Skin - Flush skin with plenty of water.

Clothing - Wash clothing before reuse.

DATE Revised 6-12-78 SIGNATURE K. T. Shen

KTS:cm

PLASTICS & ADDITIVES DIVISION
CIBA-GEIGY Corporation
Ardsley, New York 10502
(914) 478-3137

CIBA—GEIGY

SAFETY DATA SHEET

The information and recommendations contained herein are based upon data believed to be correct. However, no guarantee or warranty of any kind expressed or implied is made with respect to the information contained herein.

SECTION I.

TRADE NAME	PRODUCT TYPE
Araldite 509	Modified Liquid Epoxy Resin
CHEMICAL FAMILY: Epoxides	

SECTION II. HAZARDOUS INGREDIENTS

INGREDIENT	%	TLV (UNITS)	INGREDIENT	%	TLV (UNITS)

SECTION III. PHYSICAL DATA

BOILING POINT (°F.)		SOLUBILITY IN WATER	Insoluble
MELTING POINT (°F.)		SPECIFIC GRAVITY (H_2O=1) @ 77°F	1.12
VAPOR PRESSURE (mm Hg.)		PERCENT VOLATILE BY VOLUME (%)	
VAPOR DENSITY (AIR=1)		EVAPORATION RATE (=1)	
APPEARANCE AND ODOR	Clear colorless to light straw colored, low viscosity liquid.		

SECTION IV. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (°F.) (Method Used)	250 (Pensky-Martens Closed Cup)	FLAMMABLE LIMITS IN AIR	LEL / UEL
EXTINGUISHING MEDIA	Carbon dioxide, foam, dry chemical		

SPECIAL FIRE FIGHTING PROCEDURES

Use self contained breathing apparatus.

UNUSUAL FIRE AND EXPLOSION HAZARDS

No unusual hazards. The product should be handled as a combustible material.

SECTION V. REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID
	STABLE	X	
INCOMPATIBILITY (Materials to Avoid)	Strong oxidizing agents		
HAZARDOUS DECOMPOSITION PRODUCTS	Carbon monoxide and/or carbon dioxide		
HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	

[illegible] 7/75

SECTION VI. HEALTH HAZARD DATA

ORAL: LD_{50}	>7,000 mg/kg
DERMAL: LD_{50}	(rabbit) >6,000 mg/kg
IRRITATION: SKIN	Mild — SPI CLASS. 3
EYE	
SENSITIZATION	Moderate
THRESHOLD LIMIT VALUE	
RESPIRATORY	
EFFECTS OF OVEREXPOSURE	Mild irritation, possible sensitization
EMERGENCY & FIRST AID PROCEDURES:	Call a physician
INHALATION	Remove to fresh air. Give oxygen and artificial respiration if necessary.
INGESTION	If conscious, give water or milk and induce vomiting.
SKIN	Wash with soap and water.
EYES	Flush with water for 15 minutes.
OTHER	

SECTION VII. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Remove all sources of ignition.

Absorb on combustible material for proper disposal.

Flush contaminated areas with water.

WASTE DISPOSAL METHOD

Incineration in accordance with local pollution regulation and ordinance.

SECTION VIII. SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify Type)	NIOSH approved organic vapor respirator recommended.
PROTECTIVE CLOTHING	Impervious gloves
EYE PROTECTION	Splash-proof goggles
VENTILATION	General mechanical ventilation and local exhaust.

SECTION IX. SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING, STORING ETC.

WARNING! Causes Irritation
May Cause Sensitization

Avoid contact with eyes, skin and clothing.

Wash thoroughly after handling.

FIRST AID: In case of contact,
Eyes - Immediately flush eyes with plenty of water for at least 15 minutes. Call a physician.

Skin - Flush skin with plenty of water

Clothing - Wash clothing before reuse.

DATE Revised 10-26-77 SIGNATURE: [signature]

PLASTICS & ADDITIVES DIVISION
CIBA-GEIGY Corporation
Ardsley, New York 10502
(914) 478-3137

CIBA—GEIGY

SAFETY DATA SHEET

The information and recommendations contained herein are based upon data believed to be correct. However, no guarantee or warranty of any kind expressed or implied is made with respect to the information contained herein.

SECTION I.

TRADE NAME	PRODUCT TYPE
ARALDITE 471 X-75	Epoxy Resin Solution
CHEMICAL FAMILY: Epoxides	

SECTION II. HAZARDOUS INGREDIENTS

INGREDIENT	%	TLV (UNITS)	INGREDIENT	%	TLV (UNITS)
Xylene	ca.25	100ppm			

SECTION III. PHYSICAL DATA

BOILING POINT (°F.)		SOLUBILITY IN WATER	Very Slight
MELTING POINT (°F.)		SPECIFIC GRAVITY (H_2O=1) At 77°F	1.08
VAPOR PRESSURE (mm Hg.)		PERCENT VOLATILE BY VOLUME (%)	
VAPOR DENSITY (AIR=1)		EVAPORATION RATE (=1)	
APPEARANCE AND ODOR	Clear colorless to slightly yellow liquid with aromatic odor.		

SECTION IV. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (°F.) (Method Used)	FLAMMABLE LIMITS IN AIR	LEL	UEL
88 (Pensky-Martens Closed Cup)	% (Xylene)	1.0	7.0

EXTINGUISHING MEDIA: Carbon dioxide, dry chemical, foam

SPECIAL FIRE FIGHTING PROCEDURES: Use self-contained breathing apparatus.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Moderate when vapor is exposed to flame.

SECTION V. REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID
	STABLE	X	

INCOMPATIBILITY (Materials to Avoid): Strong oxidizing agents

HAZARDOUS DECOMPOSITION PRODUCTS: Carbon monoxide and/or carbon dioxide

HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	

D-11114 7/3

SECTION VI. HEALTH HAZARD DATA

ORAL: LD_{50}	1.85 ml/kg (Solvent
DERMAL: LD_{50}	
IRRITATION: SKIN	Moderate — SPI CLASS. 3
EYE	Irritant (Solvent)
SENSITIZATION	Skin sensitizer (Solvent)
THRESHOLD LIMIT VALUE	
RESPIRATORY	
EFFECTS OF OVEREXPOSURE	Moderate irritation. Stupor.
EMERGENCY & FIRST AID PROCEDURES:	Call a physician
INHALATION	Remove to fresh air. Oxygen and artificial respirator if necessary.
INGESTION	Do not induce vomiting.
SKIN	Remove contaminated clothing. Wash with soap and water.
EYES	Flush with plenty of water for at least 15 minutes.
OTHER	

SECTION VII. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Remove all sources of ignition

Absorb on combustible material for proper disposal

Flush contaminated areas with water

WASTE DISPOSAL METHOD

Incineration in accordance with local pollution regulation and ordinance.

SECTION VIII. SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify Type)	NIOSH approved organic vapor respirator recommended.
PROTECTIVE CLOTHING	Impervious gloves
EYE PROTECTION	Splash-proof goggles
VENTILATION	General mechanical ventilation and local exhaust.

SECTION IX. SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING, STORING ETC.

WARNING! FLAMMABLE!
Causes irritation. Harmful if inhaled.
Avoid contact with eyes, skin and clothing.
Avoid breathing vapors or dust.
Use with adequate ventilation.
Keep away from heat, sparks and open flame.

Keep container closed.

FIRST AID: In case of contact,

Flush skin with plenty of water.

Flush eyes with plenty of water for at least 15 minutes.

Call a physician. Wash clothing before reuse.

DATE Revised 12-30-77 SIGNATURE: K. T. Shen

K.T.S:cm

MATERIAL SAFETY DATA SHEET

DOW

Reprinted from computerized information supplied by the Dow Quality Assurance Data Center

DOW CHEMICAL CANADA INC., Sarnia, Ontario N7T 7K7

EMERGENCY PHONE NUMBERS: SARNIA (519) 339-3711; FORT SASKATCHEWAN (403) 998-8282

EFFECTIVE DATE: 17 DEC 81 PRODUCT CODE: 19242

PRODUCT NAME: D.E.R. (R) 324 EPOXY RESIN MSD: 0821

INGREDIENTS (TYPICAL VALUES-NOT SPECIFICATIONS)	: % :
REACTION PRODUCTS OF EPICHLOROHYDRIN AND BISPHENOL A	: 83 :
ALKYL GLYCIDYL ETHER (C12-C14)	: 17 :

SECTION 1 PHYSICAL DATA

BOILING POINT: NOT APPLICABLE : SOL. IN WATER: NONE
VAP PRESS: NOT APPLICABLE : SP. GRAVITY: 1.11
VAP DENSITY (AIR=1): NOT APPLIC. : % VOLATILE BY VOL: <1.00

APPEARANCE AND ODOR: CLEAR (LIGHT YELLOW) LIQUID OF LOW VISCOSITY.

SECTION 2 FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: 350F : FLAMMABLE LIMITS
METHOD USED: P.M.C.C. : LFL: NOT DETER. UFL: NOT DETER.

EXTINGUISHING MEDIA: FOAM, CO2, DRY CHEMICAL.

SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS: NONE.

SECTION 3 REACTIVITY DATA

STABILITY: EXCESSIVE HEATING OVER LONG PERIODS OF TIME DEGRADES THE RESIN. FREEZING MAY CAUSE A TEMPORARY HAZINESS TO DEVELOP. FIRE CONDITIONS INCREASE VISCOSITY AND EEW.

INCOMPATIBILITY: ----

HAZARDOUS DECOMPOSITION PRODUCTS: ----

HAZARDOUS POLYMERIZATION: WILL NOT OCCUR BY ITSELF, BUT MASSES OF MORE THAN 1 POUND OF PRODUCT PLUS AN ALIPHATIC AMINE WILL CAUSE IRREVERSIBLE POLYMERIZATION WITH CONSIDERABLE HEAT BUILDUP.

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES

ACTION TO TAKE FOR SPILLS: SOAK UP IN ABSORBENT MATERIAL OR SCRAPE UP. RESIDUAL CAN BE REMOVED WITH NON-FLAMMABLE SOLVENT SUCH AS METHYLENE CHLORIDE.

(CONTINUED ON PAGE 2)

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

DOW CHEMICAL CANADA INC. SARNIA, ONTARIO N7T 7NI EMERGENCY PHONE: 519-339-3711

EFFECTIVE DATE: 17 DEC 81 PRODUCT CODE: 19242
PRODUCT (CONT'D): D.E.R. (R) 324 EPOXY RESIN MSD: 0821

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES (CONTINUED)

DISPOSAL METHOD: BURN IN ADEQUATE INCINERATOR OR BURY IN APPROVED LANDFILL.

SECTION 5 HEALTH HAZARD DATA

EYE: MAY CAUSE IRRITATION.

SKIN CONTACT: MAY CAUSE IRRITATION; MAY CAUSE ALLERGIC SKIN RESPONSE.

SKIN ABSORPTION: NOT LIKELY TO BE ABSORBED IN TOXIC AMOUNTS.

INGESTION: PROBABLE LOW ACUTE ORAL TOXICITY.

INHALATION: NO GUIDE FOR CONTROL KNOWN.

SYSTEMIC & OTHER EFFECTS: VAPOR, FUMES, OR SOLID COULD CAUSE SENSITIZATION RESPONSE.

SECTION 6 FIRST AID

EYES: IRRIGATION OF THE EYE IMMEDIATELY WITH WATER FOR FIVE MINUTES IS GOOD SAFETY PRACTICE. CONSULT MEDICAL.

SKIN: CONTACT WILL PROBABLY CAUSE NO MORE THAN IRRITATION. WASH OFF IN FLOWING WATER OR SHOWER. CONSULT MEDICAL. DECONTAMINATE CLOTHING AND ACCESSORIES BEFORE REUSE.

INGESTION: LOW IN TOXICITY. INDUCE VOMITING IF LARGE AMOUNTS ARE INGESTED.

INHALATION: REMOVE TO FRESH AIR IF EFFECTS OCCUR. CONSULT MEDICAL.

NOTE TO PHYSICIAN:
EYES: INJURY IS UNLIKELY. STAIN FOR EVIDENCE OF CORNEAL INJURY.
SKIN: KNOWN OR SUSPECTED SKIN SENSITIZER. MAY CAUSE DERMATITIS. TREAT AS ANY CONTACT DERMATITIS.
RESPIRATORY: MAY CAUSE MILD IRRITATION.
ORAL: LOW IN TOXICITY.
GENERAL: CONSULT STANDARD LITERATURE. NO SPECIFIC ANTIDOTE. TREATMENT BASED ON THE SOUND JUDGMENT OF THE PHYSICIAN AND THE INDIVIDUAL REACTIONS OF THE PATIENT.

SECTION 7 SPECIAL HANDLING INFORMATION

VENTILATION: GOOD ROOM VENTILATION USUALLY ADEQUATE FOR MOST OPERATIONS.

RESPIRATORY PROTECTION: NONE NORMALLY NEEDED. FOR EMERGENCIES, A SELF-CONTAINED BREATHING APPARATUS OR A FULL-FACE RESPIRATOR AS APPROVED BY NIOSH IS RECOMMENDED.

PROTECTIVE CLOTHING: CLEAN, BODY-COVERING CLOTHING. IN ADDITION, RUBBER GLOVES, BOOTS, APRON, GAUNTLETS, AND A FACE SHIELD IN ADDITION TO RECOMMENDED EYE PROTECTION DEPENDING UPON THE EXTENT AND SEVERITY OF EXPOSURE LIKELY.

EYE PROTECTION: SAFETY GLASSES WITHOUT SIDE SHIELDS.

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: SEE DOW BULLETIN ENTITLED, 'STORAGE, HANDLING, AND TOXICITY OF DOW EPOXY RESIN' AND 'D.E.R. 324 EPOXY RESIN'. PRACTICE GOOD CAUTION AND PERSONAL CLEANLINESS TO AVOID SKIN AND EYE CONTACT. AVOID BREATHING VAPORS OF HEATED MATERIAL.

ADDITIONAL INFORMATION: 17 DEC 81 REVISED FROM 28 SEP 79 -- INGREDIENT SECTION.

LAST PAGE

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY
THE INFORMATION HEREIN IS GIVEN IN GOOD FAITH, BUT NO WARRANTY, EXPRESSED OR IMPLIED, IS MADE. CONSULT THE DOW CHEMICAL COMPANY FOR FURTHER INFORMATION.

MATERIAL SAFETY DATA SHEET

DOW

Reprinted from computerized information supplied by the Dow Quality Assurance Data Center

DOW CHEMICAL CANADA INC., Sarnia, Ontario N7T 7K7

EMERGENCY PHONE NUMBERS: SARNIA (519) 339-3711; FORT SASKATCHEWAN (403) 998-8282

EFFECTIVE DATE: 16 OCT 79 PRODUCT CODE: 19314

PRODUCT NAME: D.E.R. (R) 661 EPOXY RESIN MSD: 0360

INGREDIENTS (TYPICAL VALUES-NOT SPECIFICATIONS)	: % :
SOLID REACTION PRODUCTS OF EPICHLOROHYDRIN AND BISPHENOL A	: :

SECTION 1 PHYSICAL DATA

BOILING POINT: NOT APPLICABLE : SOL. IN WATER: NONE
VAP PRESS: NOT APPLICABLE : SP. GRAVITY: 1.18
VAP DENSITY (AIR=1): NOT APPLIC. : % VOLATILE BY VOL: NOT APPLICABLE
APPEARANCE AND ODOR: PALE YELLOW SOLID (FLAKES).

SECTION 2 FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: NOT APPLICABLE : FLAMMABLE LIMITS (STP IN AIR)
METHOD USED: ---- : LFL: NOT DETER. UFL: NOT DETER.
EXTINGUISHING MEDIA: WATER FOG, CO2, DRY CHEMICAL.
SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS: SOLID EPOXY RESINS DUST FREELY WHEN HANDLED. THE CONFINED DUST, WHEN SUSPENDED IN AIR, IS FLAMMABLE AND POSES A DEFINITE FIRE AND EXPLOSION HAZARD. GOOD HOUSEKEEPING AND DUST CONTROL ARE REQUIRED.

SECTION 3 REACTIVITY DATA

STABILITY: ----
INCOMPATIBILITY: ACID, BASE.
HAZARDOUS DECOMPOSITION PRODUCTS: ----
HAZARDOUS POLYMERIZATION: WILL NOT OCCUR BY ITSELF, BUT MASSES OF MORE THAN 1 POUND OF PRODUCT PLUS AN ALIPHATIC AMINE WILL CAUSE IRREVERSIBLE POLYMERIZATION WITH CONSIDERABLE HEAT BUILDUP.

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES

ACTION TO TAKE FOR SPILLS (USE APPROPRIATE SAFETY EQUIPMENT): SWEEP UP AND DISCARD.
DISPOSAL METHOD: BURN IN ADEQUATE INCINERATOR OR BURY IN AN APPROVED LANDFILL. COMPLY WITH LOCAL, STATE, AND FEDERAL REGULATIONS.

(CONTINUED ON PAGE 2)
(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY.

EFFECTIVE DATE: 16 OCT 79 PRODUCT CODE: 19314
PRODUCT (CONT'D): D.E.R. (R) 661 EPOXY RESIN MSD: 0369

SECTION 5 HEALTH HAZARD DATA

INGESTION: LOW SINGLE DOSE TOXICITY, LD50 (RAT) GREATER THAN 2000 MG/KG.
EYE CONTACT: MINOR TRANSIENT IRRITATION.
SKIN CONTACT: MINOR TO NO IRRITATION - MAY BE A VERY WEAK SKIN SENSITIZER.
SKIN ABSORPTION: NOT LIKELY TO BE ABSORBED IN TOXIC AMOUNTS.
INHALATION: NO GUIDE FOR CONTROL KNOWN. DUST MAY BE A NUISANCE. NOT CONSIDERED A PROBLEM.
EFFECTS OF OVEREXPOSURE: NONE KNOWN.

SECTION 6 FIRST AID--NOTE TO PHYSICIAN

FIRST AID PROCEDURES:

EYES: IRRIGATION OF THE EYE IMMEDIATELY WITH WATER FOR FIVE MINUTES IS GOOD SAFETY PRACTICE.
SKIN: CONTACT WILL PROBABLY CAUSE NO MORE THAN IRRITATION. WASH OFF IN FLOWING WATER OR SHOWER. WASH CLOTHING BEFORE REUSE.
INHALATION: REMOVE TO FRESH AIR IF EFFECTS OCCUR. CALL PHYSICIAN AND/OR TRANSPORT TO MEDICAL FACILITY.
INGESTION: LOW IN TOXICITY. INDUCE VOMITING IF LARGE AMOUNTS ARE INGESTED.

NOTE TO PHYSICIAN:

EYES: MAY CAUSE MILD IRRITATION. STAIN FOR EVIDENCE OF CORNEAL INJURY. INJURY IS UNLIKELY.
SKIN: MAY CAUSE MILD IRRITATION. TREAT AS ANY CONTACT DERMATITIS. KNOWN OR SUSPECTED MILD SKIN SENSITIZER. NOT LIKELY TO BE ABSORBED IN TOXIC AMOUNTS.
RESPIRATORY: MAY CAUSE MILD IRRITATION. BRONCHODILATORS, EXPECTORANTS, AND ANTITUSSIVES MAY BE OF HELP.
ORAL: LOW IN TOXICITY.
GENERAL: HUMAN EFFECTS NOT ESTABLISHED. NO SPECIFIC ANTIDOTE. TREATMENT BASED ON THE SOUND JUDGMENT OF THE PHYSICIAN AND THE INDIVIDUAL REACTIONS OF THE PATIENT.

SECTION 7 SPECIAL HANDLING INFORMATION

VENTILATION: GOOD VENTILATION CONSIDERED ADEQUATE FOR MOST INDUSTRIAL OPERATIONS.
RESPIRATORY PROTECTION: NONE LIKELY NEEDED.
PROTECTIVE CLOTHING: CLEAN, BODY-COVERING CLOTHING.
EYE PROTECTION: SAFETY GLASSES WITHOUT SIDE SHIELDS.

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: PRACTICE CAUTION AND PERSONAL CLEANLINESS. AVOID SKIN AND EYE CONTACT. AVOID BREATHING DUST OR VAPORS OF HEATED MATERIAL.

ADDITIONAL INFORMATION: REVISIONS 10/16/79 -- SECTIONS 2, 5, 6.

LAST PAGE

(R) INDICATES A REGISTERED OR TRADEMARK NAME OF THE DOW CHEMICAL COMPANY

THE INFORMATION HEREIN IS GIVEN IN GOOD FAITH, BUT NO WARRANTY, EXPRESSED OR IMPLIED, IS MADE.

MATERIAL SAFETY DATA SHEET

DOW

Reproduced from Computerized Information supplied by the Dow Quality Assurance Data Center

DOW CHEMICAL CANADA INC., Sarnia, Ontario N7T 7K7

EMERGENCY PHONE NUMBERS: SARNIA (519) 339-3711; FORT SASKATCHEWAN (403) 998-8282

EFFECTIVE DATE: 31 OCT 79 PRODUCT CODE: 19358

PRODUCT NAME: D.E.R. (R) 671-X75 EPOXY RESIN MSD: 0382

INGREDIENTS (TYPICAL VALUES-NOT SPECIFICATIONS)	: % :
SOLID RESIN	: 75 :
XYLENE	: 25 :

SECTION 1 PHYSICAL DATA

BOILING POINT: NOT APPLICABLE : SOL. IN WATER: NONE
VAP. PRESS: NEGLIGIBLE : SP. GRAVITY: 1.07
VAP. DENSITY (AIR=1): NOT APPLIC. : % VOLATILE BY VOL: 25.0

APPEARANCE AND ODOR: PALE YELLOW LIQUID, XYLENE.

SECTION 2 FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: 80F, 27C : FLAMMABLE LIMITS
METHOD USED: PMCC : LFL: NOT DETER. UFL: NOT DETER.

EXTINGUISHING MEDIA: FOAM, CO2, DRY CHEMICAL.

SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS: PRESENCE OF XYLENE REQUIRES GROUNDING. KEEP AWAY FROM POSSIBLE IGNITION SOURCES.

SECTION 3 REACTIVITY DATA

STABILITY: XYLENE MAY PRODUCE EXCESSIVE PRESSURE. SEALED DRUMS MAY RUPTURE AND IGNITE.

INCOMPATIBILITY: WATER, BASE.

HAZARDOUS DECOMPOSITION PRODUCTS: ----

HAZARDOUS POLYMERIZATION: WILL NOT OCCUR BY ITSELF, BUT MASSES OF MORE THAN 1 POUND OF PRODUCT PLUS AN ALIPHATIC AMINE WILL CAUSE IRREVERSIBLE POLYMERIZATION WITH CONSIDERABLE HEAT BUILDUP.

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES

ACTION TO TAKE FOR SPILLS: SOAK UP IN ABSORBENT MATERIAL. KEEP OPEN FLAMES AND SPARKS AWAY. RESIDUAL RESIN CAN BE REMOVED WITH NON-FLAMMABLE SOLVENT SUCH AS METHYLENE CHLORIDE.

(CONTINUED ON PAGE 2)

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

DOW CHEMICAL CANADA INC. SARNIA, ONTARIO N7T 7MI EMERGENCY PHONE: 519-339-3711

EFFECTIVE DATE: 31 OCT 79 PRODUCT CODE: 19350
PRODUCT (CONT'D): D.E.R. (R) 671-X75 EPOXY RESIN MSD: 0382

SECTION 4. SPILL, LEAK, AND DISPOSAL PROCEDURES (CONTINUED)

DISPOSAL METHOD: BURN IN ADEQUATE INCINERATOR OR BURY IN LANDFILL. COMPLY WITH LOCAL, STATE, AND FEDERAL REGULATIONS.

SECTION 5 HEALTH HAZARD DATA

EYE: MILD EYE IRRITATION BUT NO CORNEAL INJURY LIKELY.

SKIN CONTACT: UP TO MILD IRRITATION, DEPENDING UPON SEVERITY OF EXPOSURE. MAY BE A SKIN SENSITIZER.

SKIN ABSORPTION: NOT LIKELY TO BE ABSORBED. CONSIDERED TO BE LOW IN TOXICITY BY THAT ROUTE.

INGESTION: PROBABLY LOW IN SINGLE DOSE ORAL TOXICITY; LD50 GREATER THAN 2000 MG/KG.

INHALATION: ACGIH TLV IS 100 PPM FOR SOLVENT (XYLENE) (1978).

SYSTEMIC & OTHER EFFECTS: CONFUSION, FATIGUE, WEAKNESS, NAUSEA, HEADACHE, DIZZINESS.

SECTION 6 FIRST AID

EYES: IRRIGATE WITH FLOWING WATER IMMEDIATELY AND CONTINUOUSLY FOR 15 MINUTES. REFER TO MEDICAL PERSONNEL.

SKIN: CONTACT WILL PROBABLY CAUSE NO MORE THAN IRRITATION. WASH OFF IN FLOWING WATER OR SHOWER. WASH CLOTHING BEFORE REUSE. DESTROY CONTAMINATED SHOES.

INGESTION: DO NOT INDUCE VOMITING. CALL A PHYSICIAN AND/OR TRANSPORT TO EMERGENCY FACILITY.

INHALATION: REMOVE TO FRESH AIR IF EFFECTS OCCUR. CALL PHYSICIAN AND/OR TRANSPORT TO MEDICAL FACILITY. IF RESPIRATION STOPS, GIVE MOUTH-TO-MOUTH RESUSCITATION.

NOTE TO PHYSICIAN:
EYES: STAIN FOR EVIDENCE OF CORNEAL INJURY.
SKIN: MAY CAUSE DERMATITIS. TREAT AS ANY CONTACT DERMATITIS. KNOWN OR SUSPECTED MILD SKIN SENSITIZER.
RESPIRATORY: MAY CAUSE DRUNKENNESS. ANESTHETIC OR NARCOTIC EFFECT MAY OCCUR. ADMINISTER OXYGEN IF AVAILABLE.
ORAL: PROBABLY LOW IN TOXICITY. MAY CAUSE REACTION SIMILAR TO PETROLEUM OR PETROLEUM-LIKE SOLVENT. IF LAVAGE IS PERFORMED, SUGGEST ENDOTRACHEAL AND/OR ESOPHAGOSCOPIC CONTROL.
SYSTEMIC: ABOVE INFORMATION BASED ON TOX INFORMATION FOR INGREDIENTS. HUMAN EFFECTS NOT ESTABLISHED. NO SPECIFIC ANTIDOTE. TREATMENT BASED ON THE SOUND JUDGMENT OF THE PHYSICIAN AND THE INDIVIDUAL REACTIONS OF THE PATIENT.

SECTION 7 SPECIAL HANDLING INFORMATION

VENTILATION: GOOD VENTILATION. RECOMMEND CONTROL OF XYLENE VAPORS TO SUGGESTED GUIDE.

RESPIRATORY PROTECTION: NIOSH APPROVED RESPIRATORY PROTECTION REQUIRED IN ABSENCE OF PROPER ENVIRONMENTAL CONTROL. FOR EMERGENCIES, A SELF-CONTAINED BREATHING APPARATUS OR A FULL-FACE RESPIRATOR AS APPROVED BY NIOSH IS RECOMMENDED.

PROTECTIVE CLOTHING: CLEAN, BODY-COVERING CLOTHING.

EYE PROTECTION: SAFETY GLASSES WITHOUT SIDE SHIELDS.

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: PRACTICE CAUTION AND PERSONAL CLEANLINESS TO AVOID EYE AND SKIN CONTACT. TRY TO AVOID SUBJECTING RESIN TO TEMPERATURES ABOVE 100F, 38C. SEE SECTION 2: SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS.

ADDITIONAL INFORMATION: REVISIONS 8/31/79 -- FLASH POINT, METHOD USED, LFL, UFL, FIRE FIGHTING EQUIPMENT, SKIN CONTACT, INHALATION, FIRST AID, NOTE TO PHYSICIAN, SPECIAL HANDLING INFORMATION.
REVISIONS 10/31/79 -- METHOD USED, INGESTION, ORAL, PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE.

LAST PAGE

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY
THE INFORMATION HEREIN IS GIVEN IN GOOD FAITH, BUT NO WARRANTY, EXPRESSED OR IMPLIED, IS MADE. CONSULT THE DOW CHEMICAL COMPANY FOR FURTHER INFORMATION.

MATERIAL SAFETY DATA SHEET

DOW

Reprinted from computerized information supplied by the Dow Quality Assurance Data Center

DOW CHEMICAL CANADA INC., Sarnia, Ontario N7T 7K7

EMERGENCY PHONE NUMBERS: SARNIA (519) 339-3711; FORT SASKATCHEWAN (403) 998-8282

EFFECTIVE DATE: 27 FEB 79 PRODUCT CODE: 19369

PRODUCT NAME: D.E.R. (R) 732 EPOXY RESIN MSD: 0385

INGREDIENTS (TYPICAL VALUES-NOT SPECIFICATIONS)	%
EPICHLOROHYDRIN -POLYGLYCOL REACTION PRODUCT.	

SECTION 1 PHYSICAL DATA

BOILING POINT: NOT AVAIL. : SOL. IN WATER: NONE
VAP PRESS: NOT AVAIL. : SP. GRAVITY: 1.06
VAP DENSITY (AIR=1): NOT AVAIL. : % VOLATILE BY VOL: 1.00

APPEARANCE AND ODOR: LIQUID.

SECTION 2 FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: 405F : FLAMMABLE LIMITS
METHOD USED: ASTMD1310-67, TOC. : LFL: NOT DETER. UFL: NOT DETER.

EXTINGUISHING MEDIA: FOAM, CO2, DRY CHEMICAL.

SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS: NONE.

SECTION 3 REACTIVITY DATA

STABILITY: AVOID AMINE COMPOUNDS.

INCOMPATIBILITY: ACID, BASE.

HAZARDOUS DECOMPOSITION PRODUCTS: NONE KNOWN.

HAZARDOUS POLYMERIZATION: WILL NOT OCCUR BY ITSELF, BUT MASSES OF MORE THAN POUND OF PRODUCT PLUS AN ALIPHATIC AMINE WILL CAUSE IRREVERSIBLE POLYMERIZATION WITH CONSIDERABLE HEAT BUILDUP.

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES

ACTION TO TAKE FOR SPILLS: SOAK UP IN ABSORBENT MATERIAL AND DISCARD.

DISPOSAL METHOD: BURN IN ADEQUATE INCINERATOR OR BURY IN LANDFILL.

(CONTINUED ON PAGE 2)

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

DOW CHEMICAL CANADA INC. SARNIA, ONTARIO N7T 7MI EMERGENCY PHONE: 519-339-3711

EFFECTIVE DATE: 27 FEB 79 PRODUCT CODE: 1936
PRODUCT (CONT'D): D.E.R. (R) 732 EPOXY RESIN MSD: 0385

SECTION 5 HEALTH HAZARD DATA

EYE: MAY CAUSE PAIN, MODERATE IRRITATION AND TRANSIENT CORNEAL INJURY.

SKIN CONTACT: MINOR TO MODERATE IRRITATION. MAY BE A SKIN SENSITIZER.

SKIN ABSORPTION: NOT LIKELY TO BE ABSORBED IN ACUTELY TOXIC AMOUNTS.

INGESTION: LOW ACUTE ORAL TOXICITY; LD50 RAT GREATER THAN 4000 MG/KG.

INHALATION: NO GUIDE FOR CONTROL KNOWN. VOLATILITY LOW. VAPORS IRRITATING.

SYSTEMIC & OTHER EFFECTS: IRRITATION AND CENTRAL NERVOUS SYSTEM DEPRESSION (FROM VAPORS GENERATED AT 100C).

SECTION 6 FIRST AID

EYES: IRRIGATE WITH FLOWING WATER IMMEDIATELY AND CONTINUOUSLY FOR 15 MINUTES. REFER TO MEDICAL PERSONNEL.

SKIN: IN CASE OF CONTACT, IMMEDIATELY FLUSH SKIN WITH PLENTY OF WATER FOR AT LEAST 15 MINUTES WHILE REMOVING CONTAMINATED CLOTHING. CALL A PHYSICIAN. WASH CLOTHING BEFORE REUSE. DESTROY CONTAMINATED SHOES.

INGESTION: LOW IN TOXICITY. INDUCE VOMITING IF LARGE AMOUNTS ARE INGESTED.

INHALATION: REMOVE TO FRESH AIR IF EFFECTS OCCUR. CALL PHYSICIAN AND/OR TRANSPORT TO MEDICAL FACILITY.

NOTE TO PHYSICIAN:
- EYES: MAY CAUSE MODERATE IRRITATION. STAIN FOR EVIDENCE OF CORNEAL INJURY. IF CORNEA IS BURNED, INSTILL ANTIBIOTIC STEROID PREPARATION FREQUENTLY. CONSULT OPHTHALMOLOGIST.
- SKIN: MAY CAUSE MODERATE IRRITATION. TREAT AS ANY CONTACT DERMATITIS. KNOWN OR SUSPECTED MILD SKIN SENSITIZER. NOT LIKELY TO BE ABSORBED IN ACUTELY TOXIC AMOUNTS.
- RESPIRATORY: MAY CAUSE MODERATE IRRITATION. VAPORS MAY CAUSE DRUNKENESS. ADMINISTER OXYGEN IF AVAILABLE. BRONCHODILATORS, EXPECTORANTS, AND ANTITUSSIVES MAY BE OF HELP.
- ORAL: LOW IN TOXICITY.
- SYSTEMIC: HUMAN EFFECTS NOT ESTABLISHED. NO SPECIFIC ANTIDOTE. TREATMENT BASED ON SOUND JUDGMENT OF PHYSICIAN AND INDIVIDUAL REACTION OF THE PATIENT.

SECTION 7 SPECIAL HANDLING INFORMATION

VENTILATION: SUFFICIENT TO MINIMIZE EXPOSURE TO VAPORS. GOOD ROOM VENTILATION USUALLY ADEQUATE FOR MOST OPERATIONS.

RESPIRATORY PROTECTION: NONE NORMALLY NEEDED.

PROTECTIVE CLOTHING: CLEAN, BODY-COVERING CLOTHING.

EYE PROTECTION: SAFETY GLASSES WITHOUT SIDE SHIELDS.

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: PRACTICE CARE TO AVOID ALL SKIN CONTACT. AVOID BREATHING VAPORS. MORE COMPLETE INFORMATION CAN BE OBTAINED FROM OUR BULLETIN ON STORAGE, HANDLING AND TOXICITY OF DOW EPOXY RESINS.

ADDITIONAL INFORMATION: ----

LAST PAGE

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY
THE INFORMATION HEREIN IS GIVEN IN GOOD FAITH, BUT NO WARRANTY, EXPRESSED OR IMPLIED, IS MADE. CONSULT THE DOW CHEMICAL COMPANY FOR FURTHER INFORMATION.

MATERIAL SAFETY DATA SHEET

Reprinted from computerized information supplied by the Dow Quality Assurance Data Center

DOW CHEMICAL CANADA INC., Sarnia, Ontario N7T 7K7

EMERGENCY PHONE NUMBERS: SARNIA (519) 339-3711; FORT SASKATCHEWAN (403) 998-8282

EFFECTIVE DATE: 07 AUG 81 PRODUCT CODE: 19191

PRODUCT NAME: D.E.H. (R) 24 EPOXY CURING AGENT MSD: 0280

INGREDIENTS (TYPICAL VALUES-NOT SPECIFICATIONS)	: % :
ETHYLENEAMINES, MINIMUM	: 99 :

SECTION 1 PHYSICAL DATA

BOILING POINT: 260-290C (5%-DP) : SOL. IN WATER: COMPLETELY MISCIBLE
VAP PRESS: < 1 MMHG @ 20C : SP. GRAVITY: 0.973-0.981 @ 25/25C
VAP DENSITY (AIR=1): 5.04 : % VOLATILE BY VOL: LOW
APPEARANCE AND ODOR: LIGHT, STRAW-COLORED LIQUID - AMINE ODOR.

SECTION 2 FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: 245F, 118C : FLAMMABLE LIMITS (STP IN AIR)
METHOD USED: PENSKY-MARTENS C.C. : LFL: 1.0% @ 180C UFL: 3.6% @ 180C
EXTINGUISHING MEDIA: WATER FOG, ALCOHOL FOAM, CO2, DRY CHEMICAL.
SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS: USE FULL PROTECTIVE CLOTHING (SEE SECTION 7) AND A POSITIVE PRESSURE BREATHING APPARATUS.

SECTION 3 REACTIVITY DATA

STABILITY: CAN AUTOIGNITE IN AIR AT APPROXIMATELY 561F, 294C.
INCOMPATIBILITY: ACID, OXIDIZING MATERIAL, CHLORINATED ORGANIC COMPOUNDS.
HAZARDOUS DECOMPOSITION PRODUCTS: NITROGEN OXIDES WHEN BURNED.
HAZARDOUS POLYMERIZATION: WILL NOT OCCUR.

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES

ACTION TO TAKE FOR SPILLS (USE APPROPRIATE SAFETY EQUIPMENT): LARGE SPILL - DIKE UP AND DILUTE WITH COPIOUS QUANTITIES OF WATER. PUMP INTO APPROPRIATE CONTAINERS. SMALL SPILL - DILUTE WITH WATER.
DISPOSAL METHOD: LARGE QUANTITIES COULD BE RECOVERED. OTHERWISE, DISPOSE IN A LANDFILL IN ACCORDANCE WITH LOCAL, STATE, AND FEDERAL REGULATIONS. KEEP OUT OF PUBLIC WATER SUPPLIES. THE DOW CHEMICAL COMPANY MAY BE CONTACTED FOR ADVICE.

SECTION 5 HEALTH HAZARD DATA

(CONTINUED ON PAGE 2)

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

SECTION 5 HEALTH HAZARD DATA (CONTINUED)

INGESTION: LOW SINGLE DOSE ORAL TOXICITY; LD50 (RATS) 2460 MG/KG. INGESTION CAN CAUSE BURNS OF MOUTH, ESOPHAGUS, AND POSSIBLY STOMACH.
EYE CONTACT: MAY CAUSE SEVERE INJURY.
SKIN CONTACT: SHORT SINGLE EXPOSURE MAY CAUSE MODERATE IRRITATION, EVEN A MILD BURN. PROLONGED OR REPEATED EXPOSURE MAY CAUSE A SEVERE BURN. THIS MATERIAL MAY CAUSE SIGNIFICANT SENSITIZATION OR ALLERGIC RESPONSE.
SKIN ABSORPTION: MAY BE ABSORBED THROUGH SKIN IN MODERATELY TOXIC AMOUNTS. LD50 RABBITS 820 MG/KG.
INHALATION: NO GUIDE FOR CONTROL OF MIXTURE KNOWN. LOW DEGREE OF VOLATILITY. VAPORS IF GENERATED VERY DISAGREEABLE. ACGIH TLV 1 PPM DIETHYLENETRIAMINEMINE, 10 PPM ETHYLENEDIAMINE. POSSIBLE SENSITIZATION RESPONSE.
EFFECTS OF OVEREXPOSURE: DISAGREEABLE ODOR. VAPORS CAN CAUSE IRRITATION OF EYES, NOSE, THROAT AND POSSIBLY LUNGS. SENSITIZATION RESPONSE.

SECTION 6 FIRST AID--NOTE TO PHYSICIAN

FIRST AID PROCEDURES:

EYES: IMMEDIATE AND CONTINUOUS IRRIGATION WITH FLOWING WATER AT LEAST 30 MINUTES IS IMPERATIVE. PROMPT MEDICAL CONSULTATION ESSENTIAL.
SKIN: IN CASE OF CONTACT, IMMEDIATELY FLUSH SKIN WITH PLENTY OF WATER FOR AT LEAST 15 MINUTES WHILE REMOVING CONTAMINATED CLOTHING. CALL A PHYSICIAN. WASH CLOTHING BEFORE REUSE. DESTROY CONTAMINATED SHOES.
INHALATION: REMOVE TO FRESH AIR IF EFFECTS OCCUR. CALL PHYSICIAN AND/OR TRANSPORT TO MEDICAL FACILITY.
INGESTION: CORROSIVE. DO NOT INDUCE VOMITING. GIVE LARGE AMOUNTS OF WATER OR MILK IF IMMEDIATELY AVAILABLE AND TRANSPORT TO MEDICAL FACILITY.

NOTE TO PHYSICIAN:

EYES: MAY CAUSE CORNEAL INJURY OR BURN. MAY CAUSE IMPAIRMENT OF VISION. STAIN FOR EVIDENCE OF CORNEAL INJURY. IF CORNEA IS BURNED, INSTILL ANTIBIOTIC STEROID PREPARATION FREQUENTLY. CONSULT OPHTHALMOLOGIST.
SKIN: MAY CAUSE SEVERE BURN. IF BURN IS PRESENT, TREAT AS ANY THERMAL BURN. MAY BE ABSORBED IN ACUTELY TOXIC AMOUNTS. KNOWN OR SUSPECTED SKIN SENSITIZER.
RESPIRATORY: MAY CAUSE MILD IRRITATION. MAY CAUSE RESPIRATORY SENSITIZATION OR ASTHMA. BRONCHODILATORS, EXPECTORANTS, AND ANTITUSSIVES MAY BE OF HELP.
ORAL: CORROSIVE. MAY CAUSE STRICTURE. IF LAVAGE IS PERFORMED, SUGGEST ENDOTRACHEAL AND/OR ESOPHAGOSCOPIC CONTROL.
SYSTEMIC: HUMAN EFFECTS NOT ESTABLISHED. NO SPECIFIC ANTIDOTE. TREATMENT BASED ON THE SOUND JUDGMENT OF THE PHYSICIAN AND THE INDIVIDUAL REACTIONS OF THE PATIENT.

EFFECTIVE DATE: 07 AUG 81 PRODUCT CODE: 19191
PRODUCT (CONT'D): D.E.H. (R) 24 EPOXY CURING AGENT MSD: 0280

SECTION 7 SPECIAL HANDLING INFORMATION

VENTILATION: SUFFICIENT TO PREVENT VAPOR CONTACT. CONTROL VAPORS TO COMFORT LEVEL IN WORK AREA.
RESPIRATORY PROTECTION: NONE NORMALLY NEEDED. APPROVED RESPIRATORY PROTECTION REQUIRED IN ABSENCE OF PROPER ENVIRONMENTAL CONTROL. FOR EMERGENCIES, A POSITIVE-PRESSURE BREATHING APPARATUS OR A FULL-FACE RESPIRATOR IS RECOMMENDED.
PROTECTIVE CLOTHING: CLEAN, BODY-COVERING CLOTHING. IN ADDITION, RUBBER GLOVES, BOOTS, APRON, GAUNTLETS, AND A FACE SHIELD IN ADDITION TO RECOMMENDED EYE PROTECTION DEPENDING UPON THE EXTENT AND SEVERITY OF EXPOSURE LIKELY. A FULL SLICKER SUIT MAY BE REQUIRED WHERE GROSS EXPOSURE IS LIKELY, OR IF MATERIAL IS HOT (>140F).
EYE PROTECTION: CHEMICAL WORKERS GOGGLES. EYE FOUNTAIN AND WASHING FACILITIES AT WORK AREA.

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: GROUND ALL TRANSFER EQUIPMENT. HOLD BULK STORAGE UNDER NITROGEN BLANKET. MATERIAL SHOULD NOT COME IN CONTACT WITH COPPER OR COPPER-BEARING ALLOYS. EYE FOUNTAIN AND SAFETY SHOWER SHOULD BE ACCESSIBLE TO WORKERS.
ADDITIONAL INFORMATION: 07 AUG 81 REVISED FROM 13 JUN 79 -- SECTIONS 3, 4, 5, 6, 7, AND 8.

LAST PAGE

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

CONSULT THE DOW CHEMICAL COMPANY FOR FURTHER INFORMATION.

THE INFORMATION HEREIN IS GIVEN IN GOOD FAITH, BUT NO WARRANTY, EXPRESSED OR IMPLIED, IS MADE.

MATERIAL SAFETY DATA SHEET

Reprinted from computerized information supplied by the Dow Quality Assurance Data Center

DOW CHEMICAL CANADA INC., Sarnia, Ontario N7T 7K7

EMERGENCY PHONE NUMBERS: SARNIA (519) 339-3711; FORT SASKATCHEWAN (403) 998-8282

EFFECTIVE DATE: 02 OCT 81 PRODUCT CODE: 19205

PRODUCT NAME: D.E.H. (R) 39 EPOXY CURING AGENT MSD: 0579

INGREDIENTS (TYPICAL VALUES-NOT SPECIFICATIONS)	: % :
AMINOETHYLPIPERAZINE	: 85 :
OTHER ETHYLENE AMINES	: 15 :

SECTION 1 PHYSICAL DATA

BOILING POINT: 239C, 115 : SOL. IN WATER: COMPLETELY MISCIBLE
VAP PRESS: < 1 MMHG @ 20C : SP. GRAVITY: 0.982 @ 25/25C
VAP DENSITY (AIR=1): >1 : % VOLATILE BY VOL: LOW VOLATILITY
APPEARANCE AND ODOR: COLORLESS TO AMBER LIQUID - AMINE ODOR

SECTION 2 FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: 175F, 79C : FLAMMABLE LIMITS (STP IN AIR)
METHOD USED: PMCC : LFL: NOT DETER. UFL: NOT DETER.
EXTINGUISHING MEDIA: WATER FOG, ALCOHOL FOAM, CO2, AND DRY CHEMICALS
SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS: USE FULL PROTECTIVE CLOTHING (SEE SECTION 7) AND A POSITIVE PRESSURE BREATHING APPARATUS.

SECTION 3 REACTIVITY DATA

STABILITY: ----
INCOMPATIBILITY: ACID, OXIDIZING MATERIAL, HALOGENATED ORGANIC COMPOUNDS.
HAZARDOUS DECOMPOSITION PRODUCTS: OXIDES OF NITROGEN WHEN BURNED.
HAZARDOUS POLYMERIZATION: WILL NOT OCCUR.

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES

ACTION TO TAKE FOR SPILLS (USE APPROPRIATE SAFETY EQUIPMENT): USE PROPER PROTECTIVE EQUIPMENT. LARGE SPILL - DIKE UP AND DILUTE WITH COPIOUS QUANTITIES OF WATER. PUMP INTO APPROPRIATE CONTAINERS. SMALL SPILL - DILUTE WITH WATER.
DISPOSAL METHOD: LARGE QUANTITIES COULD BE RECOVERED. OTHERWISE, DISPOSE IN A LANDFILL IN ACCORDANCE WITH LOCAL REGULATIONS. KEEP OUT OF PUBLIC WATER SUPPLIES. THE DOW CHEMICAL COMPANY MAY BE CONTACTED FOR ADVICE.

(CONTINUED ON PAGE 2)
(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

EFFECTIVE DATE: 02 OCT 81 PRODUCT CODE: 19205
PRODUCT (CONT'D): D.E.H. (R) 39 EPOXY CURING AGENT MSD: 0579

SECTION 5 HEALTH HAZARD DATA

INGESTION: LOW SINGLE DOSE ORAL TOXICITY: LD50 RATS 1000-2000 MG/KG.
INGESTION CAN CAUSE BURNS OF MOUTH, ESOPHAGUS, AND POSSIBLY STOMACH.
EYE CONTACT: SEVERE INJURY AND IRRITATION: POSSIBLE LOSS OF VISION.
SKIN CONTACT: SHORT SINGLE EXPOSURE MAY CAUSE MODERATE BURN.
PROLONGED OR REPEATED EXPOSURE MAY CAUSE A SEVERE BURN. POSSIBLE SENSITIZATION OR ALLERGIC RESPONSE.
SKIN ABSORPTION: MODERATELY TOXIC. LD50 RABBITS 880 MG/KG FOR AEP (LITERATURE).
INHALATION: NO GUIDE FOR CONTROL ESTABLISHED FOR MIXTURE. ACGIH TLV IS 1 PPM FOR DIETHYLENETRIAMINE. POSSIBLE SENSITIZATION RESPONSE.
EFFECTS OF OVEREXPOSURE: DISAGREEABLE ODOR AND IRRITATION OF EYES, NOSE, THROAT AND POSSIBLY LUNGS.

SECTION 6 FIRST AID--NOTE TO PHYSICIAN

FIRST AID PROCEDURES:

EYES: IMMEDIATE AND CONTINUOUS IRRIGATION WITH FLOWING WATER FOR AT LEAST 30 MINUTES IS IMPERATIVE. PROMPT MEDICAL CONSULTATION ESSENTIAL.
SKIN: IN CASE OF CONTACT, IMMEDIATE, CONTINUED, AND THOROUGH WASHING IN FLOWING WATER FOR THIRTY MINUTES WHILE REMOVING CONTAMINATED CLOTHING AND SHOES. WASH CLOTHING BEFORE REUSE. DESTROY CONTAMINATED SHOES. PROMPT MEDICAL CONSULTATION IS ESSENTIAL.
INHALATION: REMOVE TO FRESH AIR IF EFFECTS OCCUR. CALL PHYSICIAN AND/OR TRANSPORT TO MEDICAL FACILITY.
INGESTION: DO NOT INDUCE VOMITING. CALL A PHYSICIAN AND/OR TRANSPORT TO EMERGENCY FACILITY.

NOTE TO PHYSICIAN:
EYES: MAY CAUSE CORNEAL INJURY OR BURN. STAIN FOR EVIDENCE OF CORNEAL INJURY. IF CORNEA IS BURNED, INSTILL ANTIBIOTIC STEROID PREPARATION FREQUENTLY. CONSULT OPHTHALMOLOGIST.
SKIN: MAY CAUSE MODERATE IRRITATION WITH SINGLE EXPOSURE. MAY CAUSE SEVERE BURN WITH PROLONGED EXPOSURE. MAY BE ABSORBED IN ACUTELY TOXIC AMOUNTS. KNOWN OR SUSPECTED SKIN SENSITIZER.
RESPIRATORY: GOOD WARNING PROPERTIES. MAY CAUSE MODERATE IRRITATION. ADMINISTER OXYGEN IF AVAILABLE. BRONCHODILATORS, EXPECTORANTS, AND ANTITUSSIVES MAY BE OF HELP. MAY CAUSE RESPIRATORY SENSITIZATION OR ASTHMA.
ORAL: MAY CAUSE BURN OF MUCOUS MEMBRANES. IF LAVAGE IS PERFORMED, SUGGEST ENDOTRACHEAL AND/OR ESOPHAGOSCOPIC CONTROL.
SYSTEMIC: HUMAN EFFECTS NOT ESTABLISHED. NO SPECIFIC ANTIDOTE. TREATMENT BASED ON THE SOUND JUDGMENT OF THE PHYSICIAN AND THE INDIVIDUAL REACTIONS OF THE PATIENT.

SECTION 7 SPECIAL HANDLING INFORMATION

VENTILATION: RECOMMEND CONTROL OF VAPORS TO SUGGESTED GUIDE.
RESPIRATORY PROTECTION: APPROVED RESPIRATORY PROTECTION REQUIRED IN ABSENCE OF PROPER ENVIRONMENTAL CONTROL. FOR EMERGENCIES, A SELF-CONTAINED BREATHING APPARATUS OR A FULL-FACE RESPIRATOR IS RECOMMENDED.
PROTECTIVE CLOTHING: CLEAN, BODY-COVERING CLOTHING. IN ADDITION, RUBBER GLOVES, BOOTS, APRON, GAUNTLETS, AND A FACE SHIELD IN ADDITION TO RECOMMENDED EYE PROTECTION DEPENDING UPON THE EXTENT AND SEVERITY OF EXPOSURE LIKELY. IN ADDITION, A FULL SLICKER SUIT MAY BE REQUIRED WHERE EXPOSURE IS LIKELY. THIS PROTECTIVE CLOTHING IS NEEDED WHEN SAMPLING TANK TRUCKS AS WELL AS IN OTHER INSTANCES WHEN CONTACT IS POSSIBLE.
EYE PROTECTION: CHEMICAL WORKERS GOGGLES. FACE SHIELD ALSO WHERE LIQUID CONTACT POSSIBLE SUCH AS DRUM LOADING OR UNLOADING.

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: GROUND ALL TRANSFER EQUIPMENT. HOLD BULK STORAGE UNDER NITROGEN BLANKET. THIS PRODUCT SHOULD NOT COME IN CONTACT WITH COPPER OR COPPER-BEARING ALLOYS. EYE FOUNTAIN AND SAFETY SHOWERS ACCESSIBLE TO WORKERS.
ADDITIONAL INFORMATION: 02 OCT 81 REVISED FROM 20 MAR 81 -- SECTIONS 2, 3, AND 5. (P.C. 19205 PREVIOUSLY ON 11.)

LAST PAGE

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

CONSULT THE DOW CHEMICAL COMPANY FOR FURTHER INFORMATION.

THE INFORMATION HEREIN IS GIVEN IN GOOD FAITH, BUT NO WARRANTY, EXPRESSED OR IMPLIED, IS MADE.

MATERIAL SAFETY DATA SHEET

Reprinted from computerized information supplied by the Dow Quality Assurance Data Center

DOW CHEMICAL CANADA INC., Sarnia, Ontario N7T 7K7

EMERGENCY PHONE NUMBERS: SARNIA (519) 339-3711; FORT SASKATCHEWAN (403) 998-8282

EFFECTIVE DATE: 23 SEP 81 PRODUCT CODE: 19199

PRODUCT NAME: D.E.H. (R) 52 EPOXY CURING AGENT MSD: 0520

INGREDIENTS (TYPICAL VALUES-NOT SPECIFICATIONS)	: % :
AMINE-ADDUCT EPOXY HARDENER	: 100 :

SECTION 1 PHYSICAL DATA

BOILING POINT: NOT APPLICABLE : SOL. IN WATER: SLIGHTLY
VAP PRESS: NOT APPLICABLE : SP. GRAVITY: 1.02
VAP DENSITY (AIR=1): NOT APPL. : % VOLATILE BY VOL: 0.5
APPEARANCE AND ODOR: LIGHT YELLOW LIQUID; AMINE ODOR.

SECTION 2 FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: 245F, 118C : FLAMMABLE LIMITS (STP IN AIR)
METHOD USED: COC : LFL: NOT DETER. UFL: NOT DETER.
EXTINGUISHING MEDIA: FOAM, CO2, DRY CHEMICAL.
SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS: ----

SECTION 3 REACTIVITY DATA

STABILITY: ----
INCOMPATIBILITY: ACID, CHLORINATED HYDROCARBONS.
HAZARDOUS DECOMPOSITION PRODUCTS: ----
HAZARDOUS POLYMERIZATION: WILL NOT OCCUR.

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES

ACTION TO TAKE FOR SPILLS (USE APPROPRIATE SAFETY EQUIPMENT): SOAK UP IN ABSORBENT MATERIAL. DO NOT WASH INTO AREAS THAT WILL CAUSE POLLUTION.
DISPOSAL METHOD: BURN IN ADEQUATE INCINERATOR OR BURY IN LANDFILL, IN ACCORDANCE WITH LOCAL, STATE AND FEDERAL REGULATIONS.

SECTION 5 HEALTH HAZARD DATA

INGESTION: MODERATE SINGLE DOSE ORAL TOXICITY; LD50 RAT IN RANGE OF 250-500 MG/KG. UNDILUTED MATERIAL WOULD PROBABLY BURN MUCOUS MEMBRANES.
EYE CONTACT: SEVERE INJURY AND IRRITATION, POSSIBLE LOSS OF VISION.
SKIN CONTACT: SHORT CONTACT (MINUTES) UP TO A MODERATE BURN. POSSIBLE SENSITIZER.

(CONTINUED ON PAGE 2)
(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

EFFECTIVE DATE: 23 SEP 81 PRODUCT CODE: 19199
PRODUCT (CONT'D): D.E.H. (R) 52 EPOXY CURING AGENT MSD: 0520

SECTION 5 HEALTH HAZARD DATA (CONTINUED)

SKIN ABSORPTION: APPARENTLY NOT READILY ABSORBED; 10% AQUEOUS SOLUTION WAS NOT ABSORBED IN ACUTELY TOXIC AMOUNTS.
INHALATION: POSSIBLE ALLERGIC RESPIRATORY ASTHMA.
EFFECTS OF OVEREXPOSURE: SEVERE BURNS, SENSITIZATION RESPONSE, LIVER AND KIDNEY INJURY.

SECTION 6 FIRST AID--NOTE TO PHYSICIAN

FIRST AID PROCEDURES:

EYES: IMMEDIATE AND CONTINUOUS IRRIGATION WITH FLOWING WATER FOR AT LEAST 30 MINUTES IS IMPERATIVE. PROMPT MEDICAL CONSULTATION IS ESSENTIAL.
SKIN: IMMEDIATELY FLUSH WITH PLENTY OF WATER FOR AT LEAST FIFTEEN MINUTES WHILE REMOVING CONTAMINATED CLOTHING.
INHALATION: REMOVE TO FRESH AIR IF EFFECTS OCCUR.
INGESTION: CORROSIVE. DO NOT INDUCE VOMITING. GIVE LARGE AMOUNTS OF WATER OR MILK IF AVAILABLE AND TRANSPORT TO MEDICAL FACILITY.

NOTE TO PHYSICIAN:
EYES: MAY CAUSE IMPAIRMENT OF VISION. STAIN FOR EVIDENCE OF CORNEAL INJURY. IF CORNEA IS BURNED, INSTILL ANTIBIOTIC STEROID PREPARATION FREQUENTLY. CONSULT OPHTHALMOLOGIST.
SKIN: IF BURN IS PRESENT, TREAT AS ANY THERMAL BURN. KNOWN OR SUSPECTED SKIN SENSITIZER.
RESPIRATORY: MAY CAUSE RESPIRATORY SENSITIZATION OR ASTHMA.
ORAL: MODERATE ORAL TOXICITY. MAY CAUSE BURN OF MUCOUS MEMBRANES. IF LAVAGE IS PERFORMED SUGGEST ENDOTRACHEAL AND/OR ESOPHAGOSCOPIC CONTROL.
SYSTEMIC: PROBABLY WOULD PRODUCE NO MORE THAN MILD ILLNESS WITH SPONTANEOUS RECOVERY. NO SPECIFIC ANTIDOTE. SUPPORTIVE CARE. TREATMENT BASED ON SOUND JUDGMENT OF PHYSICIAN AND THE INDIVIDUAL REACTIONS OF THE PATIENT. MAY CAUSE KIDNEY AND LIVER DAMAGE.

SECTION 7 SPECIAL HANDLING INFORMATION

VENTILATION: RECOMMEND CONTROL OF VAPOR TO SUGGESTED GUIDE.
RESPIRATORY PROTECTION: APPROVED ORGANIC-TYPE VAPOR RESPIRATOR REQUIRED IN ABSENCE OF PROPER ENVIRONMENTAL CONTROL.
PROTECTIVE CLOTHING: CLEAN, BODY-COVERING CLOTHING. IN ADDITION, RUBBER GLOVES, BOOTS, APRON, GAUNTLETS, AND A FACE SHIELD IN ADDITION TO RECOMMENDED EYE PROTECTION DEPENDING UPON THE EXTENT AND SEVERITY OF EXPOSURE LIKELY.
EYE PROTECTION: CHEMICAL WORKERS GOGGLES.
FULL FACE SHIELD MAY BE DESIRED, DEPENDING UPON CIRCUMSTANCES.
EYE FOUNTAIN AND WASH FACILITIES AT WORK AREA.

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: PRACTICE CAUTION AND PERSONAL CLEANLINESS. PREVENT EYE AND SKIN CONTACT. AVOID BREATHING FUMES, IF GENERATED. FOR MORE COMPLETE INFORMATION, SEE DOW BULLETIN ON 'STORAGE, HANDLING AND TOXICITY OF DOW EPOXY RESINS.'
ADDITIONAL INFORMATION: 23 SEP 81 REVISED FROM 16 JAN 79 -- INGREDIENT SECTION AND SECTION 1, 2, 4, 5, 6, AND 7.

LAST PAGE

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

CONSULT THE DOW CHEMICAL COMPANY FOR FURTHER INFORMATION.

THE INFORMATION HEREIN IS GIVEN IN GOOD FAITH, BUT NO WARRANTY, EXPRESSED OR IMPLIED, IS MADE.

MATERIAL SAFETY DATA SHEET

DOW

Reprinted from computerized information supplied by the Dow Quality Assurance Data Center

DOW CHEMICAL CANADA INC., Sarnia, Ontario N7T 7K7

EMERGENCY PHONE NUMBERS: SARNIA (519) 339-3711; FORT SASKATCHEWAN (403) 998-8282

EFFECTIVE DATE: 16 JAN 79 PRODUCT CODE: 19203

PRODUCT NAME: D.E.H.(R) 58 EPOXY CURING AGENT MSD: 0522

INGREDIENTS (TYPICAL VALUES-NOT SPECIFICATIONS)	%
AN AMINE ADDUCT	

SECTION 1 PHYSICAL DATA

BOILING POINT: NOT APPLICABLE : SOL. IN WATER: SLIGHT
VAP PRESS: NOT APPLICABLE : SP. GRAVITY: 1.02
VAP DENSITY (AIR=1): NOT APPL. : % VOLATILE BY VOL: < 1.0
APPEARANCE AND ODOR: YELLOW LIQUID.

SECTION 2 FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: 225F - 250F : FLAMMABLE LIMITS (STP IN AIR)
METHOD USED: ASTMD93-71,9266,PMCC : LFL: NOT DETER. UFL: NOT DETER.
EXTINGUISHING MEDIA: FOAM, CO2, DRY CHEMICAL.
SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS: ----

SECTION 3 REACTIVITY DATA

STABILITY: ----
INCOMPATIBILITY: ACID, CHLORINATED HYDROCARBONS.
HAZARDOUS DECOMPOSITION PRODUCTS: NONE UNDER NORMAL CONDITIONS.
HAZARDOUS POLYMERIZATION: WILL NOT OCCUR.

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES

ACTION TO TAKE FOR SPILLS (USE APPROPRIATE SAFETY EQUIPMENT): SOAK UP IN ABSORBENT MATERIAL. DO NOT WASH INTO AREAS THAT WILL CAUSE POLLUTION.
DISPOSAL METHOD: BURN IN ADEQUATE INCINERATOR OR BURY IN APPROVED LANDFILL.

SECTION 5 HEALTH HAZARD DATA

INGESTION: LOW SINGLE DOSE ORAL TOXICITY. LD50 RATS IS GREATER THAN 2000 MG/KG. MAY CAUSE IRRITATION OR BURNS TO MOUTH AND ESOPHAGUS.
EYE CONTACT: MAY CAUSE A SEVERE BURN.
SKIN CONTACT: PROLONGED OR REPEATED EXPOSURE MAY CAUSE A MARKED BURN.

CONTINUED ON PAGE 2)
) INDICATES A REGISTERED OR TRADEMARK NAME OF THE DOW CHEMICAL COMPANY

EFFECTIVE DATE: 16 JAN 79 PRODUCT CODE: 19203
PRODUCT (CONT'D): D.E.H. (R) 58 EPOXY CURING AGENT MSD: 0522

SECTION 5 HEALTH HAZARD DATA (CONTINUED)

SKIN CONTACT: (CONTINUED).
THIS MATERIAL MAY CAUSE SENSITIZATION OR ALLERGENIC RESPONSE.
SKIN ABSORPTION: NOT LIKELY TO BE ABSORBED IN TOXIC AMOUNTS.
INHALATION: ACGIH TLV: 1 PPM FOR DIETHYLENETRIAMINE (1977). VAPORS MAY CAUSE ALLERGENIC RESPONSE.
EFFECTS OF OVEREXPOSURE: ----

SECTION 6 FIRST AID--NOTE TO PHYSICIAN

FIRST AID PROCEDURES:

EYES: IMMEDIATE AND CONTINUOUS IRRIGATION WITH FLOWING WATER FOR AT LEAST 30 MINUTES IS IMPERATIVE. PROMPT MEDICAL CONSULTATION ESSENTIAL.
SKIN: SKIN BURN LIKELY. IMMEDIATE CONTINUOUS AND THOROUGH WASHING IN FLOWING WATER FOR 30 MINUTES IS IMPERATIVE. REMOVE CLOTHING IMMEDIATELY. DESTROY CONTAMINATED SHOES.
INHALATION: REMOVE TO FRESH AIR IF EFFECTS OCCUR. CALL PHYSICIAN AND/OR TRANSPORT TO MEDICAL FACILITY.
INGESTION: DO NOT INDUCE VOMITING. CALL A PHYSICIAN AND/OR TRANSPORT TO EMERGENCY FACILITY.
NOTE TO PHYSICIAN:
EYES: MAY CAUSE SEVERE CORNEAL INJURY. STAIN FOR EVIDENCE OF CORNEAL INJURY. IF CURNEA IS BURNED, INSTILL ANTIBIOTIC STEROID PREPARATION FREQUENTLY. CONSULT OPHTHALMOLOGIST.
SKIN: MAY CAUSE SEVERE BURN. IF BURN IS PRESENT, TREAT AS ANY THERMAL BURN. KNOWN OR SUSPECTED SKIN SENSITIZER.
RESPIRATORY: VAPORS MAY CAUSE SEVERE IRRITATION. GOOD WARNING PROPERTIES. ADMINISTER OXYGEN IF AVAILABLE. BRONCHODILATORS, EXPECTORANTS, AND ANTITUSSIVES MAY BE OF HELP. MAY CAUSE RESPIRATORY SENSITIZATION OR ASTHMA.
ORAL: LOW TO MODERATE ORAL TOXICITY. MAY CAUSE BURN OF MUCOUS MEMBRANES. IF LAVAGE IS PERFORMED SUGGEST ENDOTRACHEAL AND/OR ESOPHAGOSCOPIC CONTROL.
SYSTEMIC: INHALATION STUDIES INDICATE WITH OVEREXPOSURE KIDNEY AND LIVER ARE PROBABLY TARGET ORGANS. NO SPECIFIC ANTIDOTE. TREATMENT BASED ON THE SOUND JUDGMENT OF THE PHYSICIAN AND THE INDIVIDUAL REACTIONS OF THE PATIENT. CONSULT STANDARD LITERATURE.

SECTION 7 SPECIAL HANDLING INFORMATION

VENTILATION: RECOMMEND CONTROL OF VAPOR OR MIST TO SUGGESTED GUIDE.
RESPIRATORY PROTECTION: NIOSH APPROVED RESPIRATORY PROTECTION REQUIRED IN ABSENCE OF PROPER ENVIRONMENTAL CONTROL.
PROTECTIVE CLOTHING: CLEAN BODY COVERING CLOTHING. IN ADDITION, IMPERVIOUS GLOVES, BOOTS, APRON AS DICTATED BY CIRCUMSTANCES.
EYE PROTECTION: CHEMICAL WORKERS GOGGLES. EYE FOUNTAIN AND WASHING FACILITIES AT WORK AREA.

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: PRACTICE GOOD CAUTION AND PERSONAL CLEANLINESS TO AVOID EYE AND SKIN CONTACT. AVOID BREATHING FUMES IF GENERATED. EYE FOUNTAINS AND WASH FACILITIES IN WORK AREA. THIS PRODUCT IS CLASSIFIED AS A " CORROSIVE LIQUID".

ADDITIONAL INFORMATION: ----

LAST PAGE

(R) INDICATES A REGISTERED OR TRADEMARK NAME OF THE DOW CHEMICAL COMPANY

THE INFORMATION HEREIN IS GIVEN IN GOOD FAITH, BUT NO WARRANTY, EXPRESSED OR IMPLIED, IS MADE.

MATERIAL SAFETY DATA SHEET

DOW

Reprinted from computerized information supplied by the Dow Quality Assurance Data Center

DOW CHEMICAL CANADA INC., Sarnia, Ontario N7T 7K7

EMERGENCY PHONE NUMBERS: SARNIA (519) 339-3711; FORT SASKATCHEWAN (403) 998-8282

EFFECTIVE DATE: 09 APR 79 PRODUCT CODE: 19217

PRODUCT NAME: D.E.N. (R) 438 EPOXY NOVOLAC MSD: 0216

INGREDIENTS (TYPICAL VALUES-NOT SPECIFICATIONS)	%
A LIQUID EPOXIDIZED NOVOLAC RESIN	

SECTION 1 PHYSICAL DATA

BOILING POINT: NOT APPLICABLE : SOL. IN WATER: NOT DETER.
VAP PRESS: NOT APPLICABLE : SP. GRAVITY: APPROX. 1.16
VAP DENSITY (AIR=1): NOT APPLIC. : % VOLATILE BY VOL: 0.5-1.0
APPEARANCE AND ODOR: LIGHT YELLOW LIQUID.

SECTION 2 FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: 490F : FLAMMABLE LIMITS (STP IN AIR)
METHOD USED: ASTMD1310-67, TOC : LFL: NOT DETER. UFL: NOT DETER.
EXTINGUISHING MEDIA: FOAM, CO2, DRY CHEMICAL.
SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS: NONE.

SECTION 3 REACTIVITY DATA

STABILITY: EXCESSIVE HEATING OVER LONG PERIODS OF TIME DEGRADES THE RESIN, INCREASES VISCOSITY, AND EPOXIDE EQUIVALENT WEIGHT.
INCOMPATIBILITY: ----
HAZARDOUS DECOMPOSITION PRODUCTS: NONE UNDER NORMAL CONDITIONS.
HAZARDOUS POLYMERIZATION: WILL NOT OCCUR BY ITSELF, BUT MASSES OF MORE THAN POUND OF PRODUCT PLUS AN ALIPHATIC AMINE WILL CAUSE IRREVERSIBLE POLYMERIZATION WITH CONSIDERABLE HEAT BUILDUP.

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES

ACTION TO TAKE FOR SPILLS (USE APPROPRIATE SAFETY EQUIPMENT): SOAK UP WITH ABSORBENT MATERIAL OR SCRAPE UP. RESIDUE CAN BE REMOVED WITH NON-FLAMMABLE SOLVENT SUCH AS METHYLENE CHLORIDE.
DISPOSAL METHOD: BURN IN ADEQUATE INCINERATOR OR BURY IN AN APPROVED LANDFILL.

SECTION 5 HEALTH HAZARD DATA

(CONTINUED ON PAGE 2)
(R) INDICATES A REGISTERED OR TRADEMARK NAME OF THE DOW CHEMICAL COMPANY

SECTION 5 HEALTH HAZARD DATA (CONTINUED)

INGESTION: LOW SINGLE DOSE ORAL TOXICITY; LD50 (RAT) GREATER THAN 4000 MG/KG.
EYE CONTACT: MINOR TRANSIENT IRRITATION. NO CORNEAL INJURY LIKELY.
SKIN CONTACT: ONLY MINOR IRRITATION; MAY BE A SKIN SENSITIZER.
SKIN ABSORPTION: NOT ABSORBED THROUGH SKIN IN TOXIC AMOUNTS.
INHALATION: NO GUIDE FOR CONTROL KNOWN. NOT CONSIDERED A PROBLEM UNLESS HEATED TO HIGH TEMPERATURES.
EFFECTS OF OVEREXPOSURE: ----

SECTION 6 FIRST AID--NOTE TO PHYSICIAN

FIRST AID PROCEDURES:

EYES: IRRIGATION OF THE EYE IMMEDIATELY WITH WATER FOR FIVE MINUTES IS GOOD SAFETY PRACTICE.
SKIN: CONTACT WILL PROBABLY CAUSE NO MORE THAN IRRITATION. WASH OFF IN FLOWING WATER OR SHOWER. WASH CLOTHING BEFORE REUSE. DESTROY CONTAMINATED SHOES.
INHALATION: REMOVE TO FRESH AIR IF EFFECTS OCCUR. CONSULT MEDICAL PERSONNEL.
INGESTION: LOW IN TOXICITY. INDUCE VOMITING IF LARGE AMOUNTS ARE INGESTED.

NOTE TO PHYSICIAN:
EYES: MAY CAUSE MILD IRRITATION. MAY CAUSE CORNEAL INJURY OR BURN.
SKIN: MAY CAUSE MILD IRRITATION. TREAT AS ANY CONTACT DERMATITIS. KNOWN OR SUSPECTED SKIN SENSITIZER.
RESPIRATORY: NO TOX DATA.
ORAL: LOW IN TOXICITY.
SYSTEMIC: RAT LD50 STUDIES SUGGEST LIVER AND KIDNEY ARE TARGET ORGANS FOR OVEREXPOSURE. NO SPECIFIC ANTIDOTE. TREATMENT BASED ON THE SOUND JUDGMENT OF THE PHYSICIAN AND THE INDIVIDUAL REACTIONS OF THE PATIENT.

SECTION 7 SPECIAL HANDLING INFORMATION

VENTILATION: GOOD ROOM VENTILATION USUALLY ADEQUATE FOR MOST OPERATIONS.
RESPIRATORY PROTECTION: NONE LIKELY NEEDED.
PROTECTIVE CLOTHING: CLEAN, BODY-COVERING CLOTHING.
EYE PROTECTION: SAFETY GLASSES WITH SIDE SHIELDS.

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: PRACTICE GOOD CAUTION AND PERSONAL CLEANLINESS TO AVOID SKIN AND EYE CONTACT. AVOID BREATHING VAPORS OF HEATED MATERIAL. FOR MORE COMPLETE INFORMATION, SEE DOW BULLETIN, "STORAGE, HANDLING AND TOXICITY OF DOW EPOXY RESINS."

ADDITIONAL INFORMATION: ----

LAST PAGE

(R) INDICATES A REGISTERED OR TRADEMARK NAME OF THE DOW CHEMICAL COMPANY

THE INFORMATION HEREIN IS GIVEN IN GOOD FAITH, BUT NO WARRANTY, EXPRESSED OR IMPLIED, IS MADE.

MATERIAL SAFETY DATA SHEET

DOW

Reprinted from computerized information supplied by the Dow Quality Assurance Data Center

DOW CHEMICAL CANADA INC., Sarnia, Ontario N7T 7K

EMERGENCY PHONE NUMBERS: SARNIA (519) 339-3711, FORT SASKATCHEWAN (403) 998-8282

ISSUE DATE: 18 NOV 82 PRODUCT CODE: 1934

PRODUCT NAME: D.E.R. (R) 331 EPOXY RESIN MSD: 0227

INGREDIENTS (TYPICAL VALUES-NOT SPECIFICATIONS) : % :

REACTION PRODUCTS OF EPICHLOROHYDRIN & BISPHENOL A : :

SECTION 1 PHYSICAL DATA

BOILING POINT: NOT APPLICABLE : SOL. IN WATER: NONE
VAP PRESS: NOT APPLICABLE : SP. GRAVITY: 1.16
VAP DENSITY (AIR=1): NOT APPLIC. : % VOLATILE BY VOL: 0.5 TO 1.0

APPEARANCE AND ODOR: WATER-WHITE TO YELLOW LIQUID TO SEMI-SOLID.

SECTION 2 FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: 485F, 252C : FLAMMABLE LIMITS
METHOD USED: ASTM-D93, PMCC : LFL: NOT DETER. UFL: NOT DETER.

EXTINGUISHING MEDIA: FOAM, CO2, DRY CHEMICAL.

SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS: NONE.

SECTION 3 REACTIVITY DATA

STABILITY: EXCESS HEATING OVER LONG PERIODS OF TIME DEGRADES THE RESIN.

INCOMPATIBILITY: BASE.

HAZARDOUS DECOMPOSITION PRODUCTS: NONE UNDER NORMAL CONDITIONS.

HAZARDOUS POLYMERIZATION: WILL NOT OCCUR BY ITSELF, BUT MASSES OF MORE THAN 1 POUND OF PRODUCT PLUS AN ALIPHATIC AMINE WILL CAUSE UNCONTROLLABLE POLYMERIZATION WITH CONSIDERABLE HEAT BUILDUP.

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: SOAK UP IN ABSORBENT MATERIAL OR SCRAPE UP. RESIDUAL CAN BE REMOVED WITH NON-FLAMMABLE SOLVENT SUCH AS METHYLENE CHLORIDE.

WASTE DISPOSAL METHOD: BURN IN ADEQUATE INCINERATOR OR BURY IN AN APPROVED LANDFILL.

(CONTINUED ON PAGE 2)

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

DOW CHEMICAL CANADA INC. SARNIA, ONTARIO N7T 7MI EMERGENCY PHONE: 519-339-3711

EFFECTIVE DATE: 18 NOV 82 PRODUCT CODE: 19248
PRODUCT (CONT'D): D.E.R. (R) 331 EPOXY RESIN MSD: 0227

SECTION 5 HEALTH HAZARD DATA

EYE: MINOR TRANSIENT IRRITATION. NO CORNEAL INJURY LIKELY.

SKIN CONTACT: ONLY MINOR IRRITATION, MAY BE A SKIN SENSITIZER.

SKIN ABSORPTION: NOT LIKELY TO BE ABSORBED THROUGH SKIN IN TOXIC AMOUNTS.

INGESTION: LOW ACUTE ORAL TOXICITY; LD50 (RAT) GREATER THAN 2000 MG/KG.

INHALATION: NO GUIDE FOR CONTROL KNOWN. NOT CONSIDERED A PROBLEM UNLESS HEATED TO HIGH TEMPERATURE.

SYSTEMIC & OTHER EFFECTS: NONE KNOWN.

SECTION 6 FIRST AID

EYES: IRRIGATION OF THE EYE IMMEDIATELY WITH WATER FOR FIVE MINUTES IS GOOD SAFETY PRACTICE. CONSULT MEDICAL PERSONNEL.

SKIN: CONTACT WILL PROBABLY CAUSE NO MORE THAN IRRITATION. WASH OFF IN FLOWING WATER OR SHOWER. WASH CLOTHING BEFORE REUSE.

INGESTION: LOW IN TOXICITY. INDUCE VOMITING IF LARGE AMOUNTS ARE INGESTED.

INHALATION: REMOVE TO FRESH AIR IF EFFECTS OCCUR. CONSULT MEDICAL PERSONNEL.

NOTE TO PHYSICIAN:
EYES: INJURY IS UNLIKELY. STAIN FOR EVIDENCE OF CORNEAL INJURY.
SKIN: MAY CAUSE DERMATITIS. TREAT AS ANY CONTACT DERMATITIS. KNOWN OR SUSPECTED SKIN SENSITIZER. NOT LIKELY TO BE ABSORBED IN ACUTELY TOXIC AMOUNTS.
RESPIRATORY: INJURY IS UNLIKELY.
ORAL: LOW IN TOXICITY.
SYSTEMIC: HUMAN EFFECTS NOT ESTABLISHED. NO SPECIFIC ANTIDOTE. TREATMENT BASED ON THE SOUND JUDGMENT OF THE PHYSICIAN AND THE INDIVIDUAL REACTIONS OF THE PATIENT.

SECTION 7 SPECIAL HANDLING INFORMATION

VENTILATION: GOOD ROOM VENTILATION USUALLY ADEQUATE FOR MOST OPERATIONS.

RESPIRATORY PROTECTION: NONE NORMALLY NEEDED.

PROTECTIVE CLOTHING: CLEAN, BODY-COVERING CLOTHING.

EYE PROTECTION: SAFETY GLASSES WITHOUT SIDE SHIELDS.

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: SEE DOW BULLETIN ENTITLED, 'STORAGE, HANDLING AND TOXICITY OF DOW EPOXY RESINS.' PRACTICE GOOD CAUTION AND PERSONAL CLEANLINESS TO AVOID SKIN AND EYE CONTACT. AVOID BREATHING VAPORS OF HEATED MATERIAL.

ADDITIONAL INFORMATION: 18 NOV 82 REVISED FROM 27 FEB 79 --
SECTIONS: 2, 3 AND 7

LAST PAGE

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY
THE INFORMATION HEREIN IS GIVEN IN GOOD FAITH, BUT NO WARRANTY, EXPRESSED OR IMPLIED, IS MADE. CONSULT THE DOW CHEMICAL COMPANY FOR FURTHER INFORMATION.

INDUSTRIAL HYGIENE
AUG 3 1983

Shell Canada Code 734-319

SHELL CANADA LIMITED
MATERIAL SAFETY DATA SHEET

Hazard Rating (NFPA-704M)

Information on this form is furnished to the requesting party as a customer service and is not to be used for any other purpose, reproduced or published. While the information is based on data drawn from sources considered to be reliable, Shell Canada Limited does not guarantee the accuracy of the information and any express or implied warranty with respect thereto or the results obtained from the use thereof is expressly excluded.

SECTION I

MANUFACTURES NAME SHELL CANADA LIMITED	EMERGENCY TELEPHONE NO. SHELL: 416-587-7042 (24 hrs.)
ADDRESS P.O. BOX 400, TERMINAL A, TORONTO, ONTARIO, M5W 1E1	POISON CONTROL CENTRES 416-597-1500 416-656-8090
CHEMICAL NAME, SYNONYMS AND APPLICATION	TRADE NAME EPON* CURING AGENT C-111
CHEMICAL FAMILY POLYAMINE ADDUCT	FORMULA

SECTION II HAZARDOUS INGREDIENTS*

COMPOSITION	%	SPECIES	LD_{50} mg/kg ORAL	LD_{50} mg/kg DERMAL	LC_{50} CONCENTRATION	LC_{50} HOURS
Epon Curing Agent C-111	100	RAT	3000			
*Polyamine adduct	46	RABBIT		3500		
*Oxitol++ Glycol Ether	18					
*Methyl Isobutylketone (MIBK)	18					
*Xylene	18					
*Small amounts of free DETA+						
PAH CONTENT						

REFERENCES (+) Diethylenetriamine (DETA)
(++) 2-Ethoxyethanol

The result from USA NIOSH-sponsored 19-day (7 hr/day) rat and 18-day (7 hr/day) rabbit inhalation studies indicate that 2-Ethoxyethanol was strongly embryotoxic at high exposure levels (615 ppm rabbits/765 rats) and teratogenic at lower exposure levels (160 ppm rabbits/200 ppm rats).

SECTION III PHYSICAL DATA

BOILING POINT C°(F°)		DENSITY (H_2O=1)	1.01
VAPOR PRESSURE (mmHg)		PERCENT VOLATILE BY VOLUME (%)	
VAPOR DENSITY (AIR=1)	>1	EVAPORATION RATE (= 1)	
SOLUBILITY IN WATER	PARTIAL	VISCOSITY	
APPEARANCE AND ODOR Pale yellow liquid, amine odour		AUTOIGNITION TEMP C°(F°)	

SECTION IV FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (METHOD USED) C°(F°)	FLAMMABLE LIMITS % VOL. IN AIR	Lel	Uel
<23 (73) Seta flash			

EXTINGUISHING MEDIA
Use CO_2, "alcohol" foam, water fog, dry chemicals (preferred)

SPECIAL FIRE FIGHTING PROCEDURES
Wear adequate respiratory and clothing protection. Cool fire-exposed containers with water.

UNUSUAL FIRE AND EXPLOSION HAZARDS
Nitrogen oxides may be generated on combustion. Handle as a flammable liquid.

*REGISTERED TRADE MARK - SHELL CANADA LIMITED

SECTION V HEALTH HAZARD DATA EPON CURING AGENT C-111

THRESHOLD LIMIT VALUE
Not established for product: DETA 1ppm (skin) MiBK 50 ppm(skin) Xylene 100 ppm (skin)
2-Ethoxyethanol 50 ppm - ACGIH 1982

EFFECTS OF OVEREXPOSURE

SKIN AND EYES: Highly irritating to skin and eyes. It is also a strong skin sensitizer.

INHALATION: Inhalation of vapours can cause effects such as dizziness, headache, nausea, lack of coordination. Prolonged and repeated overexposure

INGESTION: can cause injury to liver, kidneys and blood forming organs.

CARCINOGENIC HAZARD:

EMERGENCY AND FIRST AID PROCEDURES

INHALATION: Remove victim from further exposure and restore breathing if required

SKIN AND EYES: Wash contaminated skin with mild soap and water. Immediately flush eyes with water for at least 15 minutes. OBTAIN MEDICAL ATTENTION

INGESTION: IMMEDIATELY.

SECTION VI REACTIVITY DATA

STABLE	X	UNSTABLE		CONDITIONS TO AVOID	Excessive heat; all ignition sources

INCOMPATIBLE MATERIALS Strong oxidizing agents

HAZARDOUS DECOMPOSITION PRODUCTS CO_2, nitrogen oxides on combustion

HAZARDOUS POLYMERIZATION	YES		NO	X	CONDITIONS TO AVOID	Exothermic reaction when cured with epoxy resin

SECTION VII SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED Eliminate all ignition sources. Wear adequate respiratory and clothing protection. Pump material into a salvage vessel. Small spills absorb with absorbent material. Remove to a container.

TRANSPORT CANADA
24 HR EMERGENCY TELEPHONE
TOLL FREE (613) 996-6666

WASTE DISPOSAL METHOD Dispose of in an appropriate facility in compliance with local regulations. Landfill in an (government) approved site or controlled burning (approved incinerator). Keep this material out of surface waters and any water courses or sewers entering/leading to surface waters.

SECTION VIII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify type) Emergencies - approved ammonia respirator or air-supplied respirator

VENTILATION
- **LOCAL EXHAUST** Must be provided
- **MECHANICAL (General)** Explosion-proof ventilation required in all operations (including drum opening)

PROTECTIVE GLOVES Impervious rubber gloves

EYE PROTECTION Chemical safety goggles or face shield to prevent eye/face contact

OTHER Overalls, apron

SECTION IX SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING, STORAGE AND USE:
Store in cool, well-ventilated area, away from heat, open flames and ignition sources. Handle as a flammable liquid. This material is a sensitizer. Avoid any direct contact. Avoid breathing vapours. Launder contaminated clothing before re-use. Use normal, good, personal hygiene.

SHELL CANADA LIMITED

PER Rudy J. Fliegl R.J. Fliegl

DATE MAY 1983

Shell Canada Limited assumes no responsibility for injury to vendee or third persons proximately caused by the material if reasonable safety procedures are not adhered to as stipulated in the data sheet. Additionally Shell Canada Limited, assumes no responsibility for injury to vendee or third persons proximately caused by abnormal use of the material even if reasonable safety procedures are followed. Futhermore, vendee assumes the risk in his use of the material.

Shell Canada Code 730-280

INDUSTRIAL HYGIENE
JUN 9 1977

SHELL CANADA LIMITED

MATERIAL SAFETY DATA SHEET

HAZARD RATING: 3 / 2 / 0

Information on this form is furnished to the requesting party as a customer service and is not to be used for any other purpose, reproduced or published. While the information is based on data drawn from sources considered to be reliable, Shell Canada Limited does not guarantee the accuracy of the information and any express or implied warranty with respect thereto or to the results obtained from the use thereof is expressly excluded.

SECTION I

MANUFACTURER'S NAME: SHELL CANADA LIMITED	EMERGENCY TELEPHONE NO.: 416-597-7042
ADDRESS: P.O. BOX 400, TERMINAL A, TORONTO, ONTARIO, M5W 1E1	
CHEMICAL NAME AND SYNONYMS: 4,4'-Isopropylidenediphenol-Epichlorohydrin Resin Sol'n	TRADE NAME: EPON* 1007-CT-55
CHEMICAL FAMILY: Epoxy Resin Solution	FORMULA:

SECTION II HAZARDOUS INGREDIENTS*

COMPOSITION	%	SPECIES	LD_{50} ORAL	LD_{50} DERMAL	LC_{50} CONCENTRATION	LC_{50} HOURS
Epon Resin 1007	55	RAT	(MIBK) 20800mg/kg		4000 ppm	4H
Methyl Isobutyl Ketone (MIBK)		RAT	(TOLUNE) 3000mg/kg		"	"
/Tolune mixture (1:1)	45	RAT	(EPON 1007) 2.2g/kg		(INTRAPERITONEAL)	
Data Taken From: (Pure Substances Only)						
-Shell Chemical Co. Industrial Hygiene Bulletin,			SC:57:95			
-NIOSH 1974 Toxic Substances List						
-"ITI" Toxic and Hazardous Industrial Chemicals Manual, 1975						
-Handbook of Industrial Toxicology, Plunkett, 1976						

SECTION III PHYSICAL DATA

BOILING POINT °F (°C) of MIBK/Toluene	240(115)	SPECIFIC GRAVITY (H_2O=1) @ 68°F (20°C)	1.007
VAPOR PRESSURE (mmHg) @ 70°F (21°C)	18.3	PERCENT VOLATILE BY VOLUME (%) MIBK/Toluene	45
VAPOR DENSITY (AIR=1) Approximately	3.5	EVAPORATE RATE (Ether =1) MIBK-Tol/Ether Estimated	20
SOLUBILITY IN WATER	SLIGHT	Viscosity @ 77°F (25°C) Centipoises	1290-3620
APPEARANCE AND ODOR: Slightly yellow liquid, Ketone odour			

SECTION IV FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used)	FLAMMABLE LIMITS	Lel	Uel
75°F (24°C) Tag Open Cup	Calculated	1.29	7.29

EXTINGUISHING MEDIA: Foam, CO_2, dry chemical

SPECIAL FIRE FIGHTING PROCEDURES: Avoid inhalation of smoke; Wear adequate repiratory protection

Handle as a flammable liquid

UNUSUAL FIRE AND EXPLOSION HAZARDS: Vapour forms explosive mixture between upper and lower explosive limits

* Registered Trade Mark - Shell Canada Limited

SECTION V HEALTH HAZARD DATA

Epon 1007-CT-55

THRESHOLD LIMIT VALUE
Methyl Isobutyl Ketone/Toluene 100 ppm (1976, ACGIH)

EFFECTS OF OVEREXPOSURE
Anesthesia -. nausea, headache, dizziness. Mildly irritating to skin and eyes;

Causes defatting dermatitis. Sensitization can occur in some individuals.

EMERGENCY AND FIRST AID PROCEDURES
Remove victim from area and restore breathing if required. Wash contaminated skin with mild soap and water. Flush eyes with water for at least 15 minutes. Contact physician. Wash contaminated clothing before reuse.

SECTION VI REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID Avoid sparks and open flames
	STABLE	X	

INCOMPATIBILITY (Materials to avoid)
Strong oxidizing agents

HAZARDOUS DECOMPOSITION PRODUCTS On pyrolysis toxic substances, such as aldehydes, Ketones, chlorinated hydrocarbons and other unidentified organics could be formed.

HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	

SECTION VII SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED
Flush with water to an open, well ventilated area. Avoid sparks and open flame sources. Remove to container.

WASTE DISPOSAL METHOD
Controlled burning or cure it and then bury it in an approved landfill site

SECTION VIII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify type)
Approved organic canister mask or air pack

VENTILATION	LOCAL EXHAUST Desirable	SPECIAL
	MECHANICAL (General) As required to maintain TLV	OTHER

protective gloves Rubber gloves	eye protection Chemical Safety goggles to guard against splashing.
OTHER PROTECTIVE EQUIPMENT Overalls, apron	

SECTION IX SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING
Store in a cool, well ventilated area. Avoid sparks and open flames. Avoid breathing vapours. Avoid direct contact with this material. Use normal, good personal hygiene.

OTHER PRECAUTIONS

SHELL CANADA LIMITED

PER Rudy Fliegl R.J. Fliegl

DATE April, 1977

Shell Canada Ltd. assumes no responsibility for injury to vendee or third persons proximately caused by the material if reasonable safety procedures are not adhered to as stipulated in the data sheet. Additionally Shell Canada Ltd. assumes no responsibility for injury to vendee or third persons proximately caused by abnormal use of the material even if reasonable safety procedures are followed. Furthermore, vendee assumes the risk in his use of the material.

Shell Canada Code 732-549

INDUSTRIAL HYGIENE
JUL 15 1977

SHELL CANADA LIMITED

MATERIAL SAFETY DATA SHEET

HAZARD RATING: 3 / 2 / 0

Information on this form is furnished to the requesting party as a customer service and is not to be used for any other purpose, reproduced or published. While the information is based on data drawn from sources considered to be reliable, Shell Canada Limited does not guarantee the accuracy of the information and any express or implied warranty with respect thereto or to the results obtained from the use thereof is expressly excluded.

SECTION I

MANUFACTURER'S NAME: SHELL CANADA LIMITED	EMERGENCY TELEPHONE NO: 416-597-7042 (bus hrs.)
ADDRESS: P.O. BOX 400, TERMINAL A, TORONTO, ONTARIO, M5W 1E1	
CHEMICAL NAME AND SYNONYMS: 4,4'-Isopropylidenediphenol-Epichlorohydrin Resin	TRADE NAME: EPON* 1001-X-75
CHEMICAL FAMILY: Epoxy Resin Solution	FORMULA:

SECTION II HAZARDOUS INGREDIENTS*

COMPOSITION	%	SPECIES	LD_{50} ORAL	LD_{50} DERMAL	LC_{50} CONCENTRATION	LC_{50} HOURS
Epon 1001 (% wt.)	75	RAT	2.4 g/Kg	(INTRAPERITONEAL) (EPON 1001)		
Xylene (% wt.)	25	RAT	4300 mg/Kg	(XYLENE)		
		HUMAN			TCLO:200ppm	(XYLENE)
Data Taken From: (Pure Substances Only)						
- 1976 NIOSH Registry of Toxic Effects of Chemical Substances						
- Shell Chemical Co. Industrial Hygiene Bulletin, SC:57-94						
- "ITI" Toxic and Hazardous Industrial Chemicals Manual, 1976						
- Handbook of Industrial Toxicology, Plunkett, 1976						
TCLO: Lowest Published Toxic Concentration						

SECTION III PHYSICAL DATA

BOILING POINT °F (°C) XYLENE 283-291	(139-144)	SPECIFIC GRAVITY (H_2O=1) @ 68°F (20°C)	1.09
VAPOR PRESSURE (mmHg) XYLENE @ 68°F (20°C)	6.0	PERCENT VOLATILE BY VOLUME (%)	25
VAPOR DENSITY (AIR=1)	3.7	EVAPORATE RATE (n BuAc=1) n BuAc/XYLENE	.59
SOLUBILITY IN WATER	NEGLIGIBLE		
APPEARANCE AND ODOR: Light coloured viscous liquid, aromatic odour.			

SECTION IV FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used)		FLAMMABLE LIMITS	Lel	Uel
75°F (25°C)	Tag Open Cup		1.0	7.0

EXTINGUISHING MEDIA: Foam, CO_2, dry chemical.

SPECIAL FIRE FIGHTING PROCEDURES: Avoid inhalation of smoke. Wear adequate respiratory protection. Handle as a flammable liquid.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Vapour forms an explosive mixture between upper and lower flammable limits

*Registered Trade Mark - Shell Canada Limited

SECTION V HEALTH HAZARD DATA

EPON 1001-X-75

THRESHOLD LIMIT VALUE
Current TLV for XYLENE 100 ppm (1976, ACGIH).

EFFECTS OF OVEREXPOSURE
Anesthesia - nausea, headache, dizziness. Moderately irritating to skin and eyes. Causes cracking, dermatitis. Sensitization can occur in some individuals.

EMERGENCY AND FIRST AID PROCEDURES
INHALATION: REMOVE victim from area and restore breathing if required.

SKIN AND EYES: Wash contaminated skin with mild soap and water. Flush eyes with water for at least 15 minutes. Contact physician. Wash contaminated clothing before reuse.

SECTION VI REACTIVITY DATA

STABILITY			CONDITIONS TO AVOID
	UNSTABLE		Avoid sparks and open flames.
	STABLE	X	

INCOMPATABILITY (Materials to avoid)
Avoid contact with strong oxidizing materials.

HAZARDOUS DECOMPOSITION PRODUCTS On pyrolysis toxic substances, such as aldehydes, ketones, chlorinated hydrocarbons and other unidentified organics could be formed.

HAZARDOUS POLYMERIZATION			CONDITIONS TO AVOID
	MAY OCCUR		
	WILL NOT OCCUR	X	Slight exothermic reaction on curing.

SECTION VII SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED
Flush with water to an open, well-ventilated area. Wear adequate respiratory protection. Avoid sparks and open flame sources. Remove to container.

WASTE DISPOSAL METHOD
Dispose of by controlled burning or cure it and then bury it in an approved landfill site.

SECTION VIII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify type)
Approved organic canister mask or air pack.

VENTILATION			
	LOCAL EXHAUST	Desirable	SPECIAL
	MECHANICAL (General)	Yes - Should be explosion-proof.	OTHER

PROTECTIVE GLOVES: Impervious rubber gloves.	EYE PROTECTION: Chemical safety goggles to guard against splashing.

OTHER PROTECTIVE EQUIPMENT
Overalls, apron.

SECTION IX SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING
Store in cool, well-ventilated area. Avoid sparks and open flame sources.

OTHER PRECAUTIONS
Avoid breathing vapours. Avoid direct contact with these materials. Use normal, good personal hygiene.

SHELL CANADA LIMITED

PER R.J. Fliegl

DATE July, 1977

Shell Canada Ltd. assumes no responsibility for injury to vendee or third persons proximately caused by the material if reasonable safety procedures are not adhered to as stipulated in the data sheet. Additionally Shell Canada Ltd. assumes no responsibility for injury to vendee or third persons proximately caused by abnormal use of the material even if reasonable safety procedures are followed. Furthermore, vendee assumes the risk in his use of the material.

INDUSTRIAL HYGIENE
NOV 6 1979

Shell Canada Code 732-519

SHELL CANADA LIMITED
MATERIAL SAFETY DATA SHEET

Hazard Rating (NFPA-704M)

Information on this form is furnished to the requesting party as a customer service and is not to be used for any other purpose, reproduced or published. While the information is based on data drawn from sources considered to be reliable, Shell Canada Limited does not guarantee the accuracy of the information and any express or implied warranty with respect thereto or the the results obtained from the use thereof is expressly excluded.

SECTION I

MANUFACTURERS NAME: SHELL CANADA LIMITED	EMERGENCY TELEPHONE NO. SHELL: 416-597-7042 (bus. hrs) POISON CONTROL CENTRES: 416-597-1500 (24 hrs.) 416-656-8080 (24 hrs.)
ADDRESS: P.O. BOX 400, TERMINAL A, TORONTO, ONTARIO, M5W 1E1	
CHEMICAL NAME AND SYNONYMS: 4, 4' ISOPROPYLIDENEDIPHENOL - EPICHLOROHYDRIN RESIN	TRADE NAME: SHELL EPON* 836-C-75
CHEMICAL FAMILY: EPOXY RESIN (SOLUTION)	FORMULA

SECTION II HAZARDOUS INGREDIENTS*

COMPOSITION	%	SPECIES	LD_{50} ORAL	LD_{50} DERMAL	LC_{50} CONCENTRATION	LC_{50} HOURS
EPON 836 (% wt)	75**	RAT	>10g/kg	(ESTIMATED)	EPON	836
METHYL ISOBUTYL KETON (MIBK)	25	RAT	2080 mg/k	(MIBK)	4 999 ppm	4 H
		MICE	(MIBK)		20 000 ppm	1.25 H
BENZENE CONTENT						
PAH CONTENT						

REFERENCES
**PRODUCT OF REACTION BETWEEN EPICHLOROHYDRIN AND BISPHENOL "A" - IN THIS PROCESS THE REACTION IS ESSENTIALLY COMPLETE.
- "ITI" TOXIC AND HAZARDOUS INDUSTRIAL CHEMICALS MANUAL, 1975
- 1977 "NIOSH" REGISTRY OF TOXIC EFFECTS OF CHEMICAL SUBSTANCES
- OCCUPATIONAL DISEASES - GUIDE TO THEIR RECOGNITION, U.S. NEW JUNE 1977

SECTION III PHYSICAL DATA

BOILING POINT °F(°C) OF MIBK	244 (118)	SPECIFIC GRAVITY (H_2O=1)	1.07
VAPOR PRESSURE (mm/Hg) OF MIBK @ 68°F 20°C	14.8	PERCENT VOLATILE BY VOLUME (%) MIBK	25
VAPOR DENSITY (AIR=1) OF MIBK	2.5	EVAPORATION RATE (nBuAc=1) OF MIBK	1.62
SOLUBILITY IN WATER		VISCOSITY	
APPEARANCE AND ODOR: AMBER, VISCOUS LIQUID, KETONE ODOUR		AUTOIGNITION TEMP °F(°C)	

SECTION IV FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (METHOD USED) °F(°C) 83 (28) TAG OPEN CUP	FLAMMABLE LIMITS % VOL. IN AIR OF MIBK	LEL 1.4	UEL 7.5

EXTINGUISHING MEDIA
USE CO_2, FOAM, DRY CHEMICALS (PREFERRED).

SPECIAL FIRE FIGHTING PROCEDURES
AVOID INHALATION OF SMOKE. WEAR ADEQUATE RESPIRATORY PROTECTION. HANDLE AS A FLAMMABLE LIQUID.

UNUSUAL FIRE AND EXPLOSION HAZARDS
VAPOUR FORMS AN EXPLOSIVE MIXTURE BETWEEN UPPER AND LOWER EXPLOSIVE LIMITS.

*REGISTERED TRADE MARK - SHELL CANADA LIMITED

SECTION V HEALTH HAZARD DATA

EPON 836-C-75

THRESHOLD LIMIT VALUE
TLV FOR MIBK 100 ppm (ACGIH) 1978

EFFECTS OF OVEREXPOSURE

SKIN AND EYES: MODERATELY IRRITATING TO SKIN AND EYES. PROLONGED OR REPEATED CONTACT MAY CAUSE CRACKING DERMATITIS. SENSITIZATION CAN OCCUR IN SOME INDIVIDUALS.

INHALATION: IRRITATING TO RESPIRATORY PASSAGES (MUCOUS MEMBRANES OR NOSE AND THROAT).

INGESTION: INHALATION OF HIGH CONCENTRATIONS MAY PRODUCE NARCOSIS, WITH SYMPTOMS OF HEADACHE, NAUSEA, DIZZINESS, INCOORPINATION AND UNCONSCIOUSNESS.

CARCINOGENIC HAZARD:

EMERGENCY AND FIRST AID PROCEDURES

INHALATION: REMOVE VICTIM TO FRESH AIR, AND RESTORE BREATHING IF REQUIRED.

SKIN AND EYES: WASH CONTAMINATED SKIN WITH MILD SOAP AND WATER. FLUSH EYES WITH WATER FOR AT LEAST 15 MIN. WASH CONTAMINATED CLOTHING BEFORE REUSE.

INGESTION: DO NOT INDUCE VOMITING. GUARD AGAINST ASPIRATION INTO LUNGS. SEEK MEDICAL ATTENTION.

SECTION VI REACTIVITY DATA

STABLE	X	UNSTABLE		CONDITIONS TO AVOID
				AVOID SPARKS, OPEN FLAMES AND ALL OTHER IGNITION SOURCES.

INCOMPATIBLE MATERIALS
AVOID CONTACT WITH STRONG OXIDIZING MATERIALS.

HAZARDOUS DECOMPOSITION PRODUCTS
ON PYROLYSIS TOXIC SUBSTANCES SUCH AS ALDEHYDES, KETONES, CHLORINATED HYDROCARBONS AND OTHER UNINDENTIFIED ORGANICS COULD BE FORMED.

HAZARDOUS POLYMERIZATION	YES		NO	X	CONDITIONS TO AVOID
					EXOTHERMIC REACTION ON CURING

SECTION VII SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED
FLUSH WITH WATER TO AN OPEN WELL-VENTILATED AREA. WEAR ADEQUATE RESPIRATORY PROTECTION. AVOID SPARKS, OPEN FLAMES AND ALL IGNITION SOURCES. REMOVE TO A CONTAINER.

WASTE DISPOSAL METHOD
DISPOSE OF BY CONTROLLED BURNING OR LANDFILL IN AN APPROVED SITE AFTER CURING.

SECTION VIII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify type)
APPROVED ORGANIC CANISTER MASK OR AIR SUPPLIED RESPIRATOR.

VENTILATION
LOCAL EXHAUST: DESIRABLE
MECHANICAL (General): TO MAINTAIN SUGGESTED TLV; ELECTRICAL AND MECHANICAL EQUIPMENT SHOULD BE SPARK PROOF

PROTECTIVE GLOVES
IMPERVIOUS RUBBER GLOVES

OTHER
OVERALLS, APRON

EYE PROTECTION
CHEMICAL SAFETY GOGGLES TO GUARD AGAINST SPLASHING.

SECTION IX SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING, STORAGE AND USE:
STORE IN COOL, WELL-VENTILATED AREA. AVOID SPARKS, OPEN FLAMES AND ALL OTHER IGNITION SOURCES. AVOID DIRECT CONTACT WITH THESE MATERIALS. HANDLE AS A FLAMMABLE LIQUID. USE NORMAL, GOOD PERSONAL HYGIENE.

SHELL CANADA LIMITED

PER R.J. FLIEGL

DATE AUGUST, 1979

Shell Canada Limited assumes no responsibility for injury to vendee or third persons proximately caused by the material if reasonable safety procedures are not adhered to as stipulated in the data sheet. Additionally Shell Canada Limited, assumes no responsibility for injury to vendee or third persons proximately caused by abnormal use of the material even if reasonable safety procedures are followed. Furthermore, vendee assumes the risk in his use of the material.

INDUSTRIAL HYGIENE
JUN 21 1982

Shell Canada Code 731-430

SHELL CANADA LIMITED
MATERIAL SAFETY DATA SHEET

Hazard Rating (NFPA-704M)

Information on this form is furnished to the requesting party as a customer service and is not to be used for any other purpose, reproduced or published. While the information is based on data drawn from sources considered to be reliable, Shell Canada Limited does not guarantee the accuracy of the information and any express or implied warranty with respect thereto or the results obtained from the use thereof is expressly excluded.

SECTION I

MANUFACTURES NAME: SHELL CANADA LIMITED	EMERGENCY TELEPHONE NO. SHELL: 416-597-7042 (24 hrs.)
ADDRESS: P.O. BOX 400, TERMINAL A, TORONTO, ONTARIO, M5W 1E1	POISON CONTROL CENTRES 416-597-1500 416-656-8090
CHEMICAL NAME, SYNONYMS AND APPLICATION: 4,4 ISOPROPYLIDENEDIPHENOL-EPICHLOROHYDRIN RESIN	TRADE NAME: SHELL EPON* 828
CHEMICAL FAMILY: EPOXY RESIN	FORMULA

SECTION II HAZARDOUS INGREDIENTS*

COMPOSITION	%	SPECIES	LD_{50} g/kg ORAL	LD_{50} g/kg DERMAL	LC_{50} CONCENTRATION	LC_{50} HOURS
Epon Resin 828	100					
		RAT	11.4 [1]	> 1.2 [2]		
BENZENE CONTENT						
PAH CONTENT						

REFERENCES

1. Hine CH. etal (1958) A.M.A. Arch.Ind. Hlth. 17, 129-144
2. Shell Data

SECTION III PHYSICAL DATA

BOILING POINT C°(F°)		DENSITY (H_2O=1) @ 20°C (68°F)	1.17
VAPOR PRESSURE (mmHg) @ 20°C (68°F)	Negligible	PERCENT VOLATILE BY VOLUME (%)	0
VAPOR DENSITY (AIR=1)		EVAPORATION RATE (=1)	NA
SOLUBILITY IN WATER	NEGLIGIBLE	VISCOSITY @ 25°C (77°F) poises	120-150
APPEARANCE AND ODOR: Clear, amber, viscous liquid in uncured form		AUTOIGNITION TEMP C°(F°)	

SECTION IV FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (METHOD USED) C°(F°)	FLAMMABLE LIMITS % VOL. IN AIR	Lel	Uel
249 (480) Cleveland Open Cup			

EXTINGUISHING MEDIA: Use CO_2, Foam, dry chemicals (preferred)

SPECIAL FIRE FIGHTING PROCEDURES: Avoid inhalation of smoke. Wear adequate respiratory protection.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Toxic fumes emitted when heated to decomposition (See Section VI)

*Registered Trade Mark - Shell Canada Limited

SECTION V HEALTH HAZARD DATA

EPON-828

THRESHOLD LIMIT VALUE: Not established.

EFFECTS OF OVEREXPOSURE

SKIN AND EYES: Moderately irritating to skin and eyes. Prolonged or repeated contact may cause skin disorders such as dermatitis. Sensitization can occur in certain individuals following repeated contact.

INHALATION:

INGESTION:

CARCINOGENIC HAZARD:

EMERGENCY AND FIRST AID PROCEDURES

INHALATION: Remove victim from to fresh air and restore breathing if required. Wash contaminated skin with mild soap and water. Flush eyes with water for at least 15 minutes. Wash contaminated clothing before reuse. DO NOT INDUCE VOMITING. GET MEDICAL HELP IMMEDIATELY.

SKIN AND EYES:

INGESTION:

SECTION VI REACTIVITY DATA

STABLE	X	UNSTABLE		CONDITIONS TO AVOID

INCOMPATIBLE MATERIALS: Avoid contact with strong oxidizing agents or mineral acids.

HAZARDOUS DECOMPOSITION PRODUCTS: On Pyrolysis highly toxic substances such as Aldenhydes, Ketones, Chlorinated hydrocarbon & other unidentified organic could be formed.

HAZARDOUS POLYMERIZATION	YES		NO		CONDITIONS TO AVOID
					Exothermic reaction on curing

SECTION VII SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: Flush with water to an open, well-ventilated area. Wear adequate respiratory protection. Guard against open flames, sparks and all other ignition sources if solvent is used. Remove to a container.

TRANSPORT CANADA
24 HR EMERGENCY TELEPHONE
TOLL FREE (613) 996-6666

WASTE DISPOSAL METHOD: Dispose of by controlled burning (approved incinerator) or landfill the absorbed material in an (Government) approved site, after curing.

SECTION VIII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify type): Approved organic canister mask or air supplied respirator.

VENTILATION

LOCAL EXHAUST: Desirable

MECHANICAL (General): Desirable, electrical & mechanical equipment should be spark-proof.

PROTECTIVE GLOVES: Neoprene Rubber Gloves

EYE PROTECTION: Chemical safety goggles to guard against splashing

OTHER: Overalls, Apron

SECTION IX SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING, STORAGE AND USE: Store in cool, well-ventilated area. Avoid direct contact with these materials. Use good, ormal personal hygiene. When heated to decomposition these materials emit highly toxic fumes.

SHELL CANADA LIMITED

PER R.G. Fleigl

DATE April, 1982

Shell Canada Limited assumes no responsibility for injury to vendee or third persons proximately caused by the material if reasonable safety procedures are not adhered to as stipulated in the data sheet. Additionally Shell Canada Limited, assumes no responsibility for injury to vendee or third persons proximately caused by abnormal use of the material even if reasonable safety procedures are followed. Futhermore, vendee assumes the risk in his use of the material.

APPENDIX VIII

EXPOSURE LIMITS FOR COMMON SUBSTANCES
ASSOCIATED WITH EPOXY RESINS

INDEX

Appendix VIIIa - Canadian Occupational Exposure Limits for Epichlorohydrin, Bisphenol A, and Some Curing Agents (Canadian Occupational Safety and Health Law - Corpus - April 1984)

Appendix VIIIb - Occupational Exposure Limits in Other Countries for Epichlorohydrin, Bisphenol A, and Epoxy Resin Curing Agents (International Labour Office, 1980; NIOSH, 1983; ACGIH, 1983/84)

Appendix VIIIc - Canadian Occupational Exposure Limits for Glycidyl Ethers Used with Epoxy Resins (Canadian Occupational Safety and Health Law - Corpus - April 1984)

Appendix VIIId - Occupational Exposure Limits in Other Countries for Glycidyl Ethers Used with Epoxy Resins (International Labour Office, 1980; NIOSH, 1983; ACGIH, 1983/84)

Appendix VIIIe - Rationale Used by ACGIH and NIOSH for Exposure Limits Established for Some Substances Used With Epoxy Resins

APPENDIX VIIIa

CANADIAN OCCUPATIONAL EXPOSURE LIMITS FOR EPICHLOROHYDRIN, BISPHENOL A, AND SOME CURING AGENTS
(Canadian Occupational Safety and Health Law - Corpus)

Province	Epichlorohydrin				Bisphenol A				Diethylenetriamine (DETA)				4,4'-Methylenedianiline (MDA)				Phthalic Anhydride				Guideline or Regulation	Date of Issue or Basis
	TWA*		STEL**		TWA		STEL		TWA		STEL		TWA		STEL		TWA		STEL			
	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)		
Alberta	2.0[S]	7.6[S]	5.0	19.0	-	-	-	-	1.0[S]	4.0[S]	3.0[S]	13.0[S]	0.1[S]	0.8[S]	0.5[S]	4.0[S]	1.0	6.0	4.0	24.0	R	1982
British Columbia	5.0[C]	20.0[C]	-	-	-	-	0.5[b]	2.8	1.0	-	1.0	-	-	-	-	-	1.0	6.0	4.0	24.0	R	1978
Manitoba	2.0	10.0	5.0	20.0	-	-	-	-	1.0[S]	4.0[S]	-	-	0.1[S]	0.8[S]	0.5[S]	4.0[S]	1.0	6.0	4.0	24.0	G	Follows current ACGIH
New Brunswick	5.0	20.0	10.0	40.0	-	-	-	-	1.0[S]	4.0[S]	-	-	-	-	-	-	1.0	6.0	4.0	24.0	R	Follows ACGIH, 1976
Newfoundland	2.0	10.0	5.0	20.0	-	-	-	-	1.0[S]	4.0[S]	-	-	0.1[S]	0.8[S]	0.5[S]	4.0[S]	1.0	6.0	4.0	24.0	R	Follows current ACGIH
Nova Scotia	2.0	10.0	5.0	20.0	-	-	-	-	1.0[S]	4.0[S]	-	-	0.1[S]	0.8[S]	0.5[S]	4.0[S]	1.0	6.0	4.0	24.0	R	Follows current ACGIH
Ontario[a]	2.0	10.0	5.0	20.0	-	-	-	-	1.0[S]	4.0[S]	-	-	-	0.04	-	-	1.0	6.0	4.0	24.0	G	Follows current ACGIH, except for MDA
Prince Edward Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	No guidelines or regulations
Quebec	5.0[C]	20.0	10.0	40.0	-	-	-	-	1.0[S]	4.0[S]	-	-	-	-	-	-	1.0	6.0	4.0	24.0	R	1979
Saskatchewan	-	-	-	-	-	-	-	-	-	4.0	-	8.0	-	0.8	-	4.0	-	6.0	-	24.0	R	1981

* Time-weighted average (TWA) exposure limit (over 8 hours unless otherwise noted).
**Short-term exposure limit (STEL) (15 minutes unless otherwise noted).

Note: C = classed as a carcinogen; S = skin; a = TWA is based on a 40-h week; b = maximum concentration should not be exceeded at any time.

[redacted] VIII.b

OCCUPATIONAL EXPOSURE LIMITS IN OTHER COUNTRIES FOR EPICHLOROHYDRIN, BISPHENOL A, AND EPOXY RESIN CURING AGENTS
(International Labour Office, 1980; NIOSH, 1983; ACGIH, 1983/84; UK Guidance Note EH40, 1983)

Country	Epichlorohydrin				Bisphenol A				Diethylenetriamine (DETA)				4,4'-Methylenedianiline (MDA)				Phthalic Anhydride				Guideline or Regulation	Date of Issue
	TWA*		STEL**		TWA		STEL		TWA		STEL		TWA		STEL		TWA		STEL			
	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)		
Australia	5	20	-	-	-	-	-	-	1[S]	4	-	-	-	-	-	-	2	12	-	-	G	1978
Belgium	5	20	-	-	-	-	-	-	1[S]	4	-	-	-	-	-	-	1	6	-	-	G	1978
Bulgaria	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	1971
Czechoslovakia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	15	R	1976
Finland	5	19	-	-	-	-	-	-	1[S]	4	-	-	-	-	-	-	2	12	-	-	G	1975
Germany (East)	-	5	-	10	-	-	-	-	-	10	-	25	-	-	-	-	-	10	-	30	R	1977
Germany (West)	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	G	1979
Great Britain	2[S]	8[S]	5[S]	20[S]	-	-	-	-	1[S]	4[S]	-	-	0.1	0.8	0.5	4	1	6	4	24	G	1983
Italy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.8	5	-	-	G	1978
Netherlands	1	4	-	-	-	-	-	-	1[S]	4	-	-	-	-	-	-	1	6	-	-	G	1978
Poland	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	R	1976
Romania	-	5	-	10	-	10	-	15	-	-	-	-	-	-	-	-	-	5	-	10	R	1975
Sweden	0.5[C]	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	12	-	-	G	1978
Switzerland	5	19	-	-	-	-	-	-	1[S]	4	-	-	-	-	-	-	0.8	5	-	-	R	1978
USSR	-	1	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	1	-	-	R	1977
United States																						
- NIOSH	-	2	-	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	G	1976
- OSHA	5	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	1976
- ACGIH	2[S]	10	5[S]	20	-	-	-	-	1[S]	4	-	-	0.1[S]	0.8	0.5[S]	4	1	6	4	24	G	1983/84
Yugoslavia	5	18	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	12	-	-	R	1971

* TWA = time-weighted average exposure limit.
**STEL = short-term exposure limit. (Generally 15 minutes, except for Great Britain which has a 10-min exposure limit.)

Note: C = classed as a carcinogen; S = skin.

Some of the ILO data published in 1980 may now be out of date if some countries follow ACGIH guidelines. For example, the current (1983-1984) ACGIH recommended level for epichlorohydrin is 10 mg/m^3 (2 ppm), while in 1980 it was 20 mg/m^3 (5 ppm).

[redacted]

APPENDIX VIIIc

CANADIAN OCCUPATIONAL EXPOSURE LIMITS FOR GLYCIDYL ETHERS USED WITH EPOXY RESINS
(Canadian Occupational Safety and Health Law - Corpus)

Province	Allyl Glycidyl Ether (AGE)				n-Butyl Glycidyl Ether (BGE)				Diglycidyl Ether (DGE)				Isopropyl Glycidyl Ether (IGE)				Phenyl Glycidyl Ether (PGE)				Guideline or Regulation	Date of Issue or Basis
	TWA		STEL		TWA		STEL		TWA[a]		STEL[aa]		TWA		STEL		TWA		STEL			
	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)		
Alberta	5[S]	23[S]	10[S]	47[S]	25	135	38	200	0.1	0.5	0.3	1.5	50	237	75	356	10	60	15	90	R	1982
British Columbia	5	22	10	44	50	270	75	400	0.5	2.8	-	-	50	240	75	360	10	60	15	90	R	1978
Manitoba	5	22	10	44	25	135	-	-	0.1	0.5	-	-	50	240	75	360	1	6	-	-	G	Follows current ACGIH
New Brunswick	5	22	10	44	50	270	50	270	0.5	2.8	0.5	2.8	50	240	75	360	10	60	15	90	R	Follows ACGIH, 1976
Newfoundland	5	22	10	44	25	135	-	-	0.1	0.5	-	-	50	240	75	360	1	6	-	-	R	Follows current ACGIH
Nova Scotia	5	22	10	44	25	135	-	-	0.1	0.5	-	-	50	240	75	360	1	6	-	-	R	Follows current ACGIH
Ontario[a]	5	23	10	47	25	130	-	-	-	-	-	-	50	237	75	356	1	6	-	-	G	Follows current ACGIH
Prince Edward Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	No guidelines or regulations
Quebec	5	22	10	44	50	270	-	-	-	-	0.5	3.0[b]	50	240	75	360	10	60	15	90	R	1979
Saskatchewan	-	22	-	44	-	135	-	169	-	0.5	-	1.5	-	240	-	360	-	6	-	12	R	1981

[a] Time-weighted average (TWA) exposure limit (over 8 hours unless otherwise noted).
[aa] Short-term exposure limit (STEL) (15 minutes unless otherwise noted).

Note: a = TWA is based on a 40-h week; b = maximum concentration must never be exceeded at any time; S = skin.

APPENDIX VIIId

OCCUPATIONAL EXPOSURE LIMITS IN OTHER COUNTRIES FOR GLYCIDYL ETHERS USED WITH EPOXY RESINS
(International Labour Office, 1980; NIOSH, 1983; ACGIH, 1983/84)

Country	Allyl Glycidyl Ether (AGE)				n-Butyl Glycidyl Ether (BGE)				Diglycidyl Ether (DGE)				Isopropyl Glycidyl Ether (IGE)				Phenyl Glycidyl Ether (PGE)				Guideline or Regulation	Date of Issue or Basis
	TWA		STEL		TWA		STEL		TWA*		STEL**		TWA		STEL		TWA		STEL			
	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)		
Australia	5	22	-	-	50	270	-	-	-	-	0.5	2.8	50	240	-	-	10	60	-	-	G	1978
Belgium	5^S	22	-	-	50	270	-	-	-	-	0.5	2.8	50	240	-	-	10	60	-	-	G	1978
Bulgaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	1971
Finland	5^S	22	-	-	50	270	-	-	-	-	0.5	2.8	50	240	-	-	10	60	-	-	G	1975
Germany (East)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	1977
Germany (West)	10	45	-	-	-	-	-	-	0.5	2.8	-	-	50	240	-	-	10^S	62	-	-	G	1979
Great Britain	5^S	22^S	10.0^S	44^S	50	270	-	-	0.5	3.0	0.5	3.0	50	240	75	360	-	-	-	-	G	1983
Italy	5^S	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	G	1978
Netherlands	5^S	22	-	-	50	270	-	-	-	-	0.5	2.8	50	240	-	-	10	60	-	-	G	1978
Poland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	1976
Romania	-	100	-	200	-	100	-	200	-	-	-	2.0	-	50	-	100	-	75	-	100	R	1975
Sweden	-	-	-	-	-	-	-	-	-	-	0.5	2.8	-	-	-	-	-	-	-	-	G	1978
Switzerland	5^S	22	-	-	50	270	-	-	-	-	0.5	2.8	50	240	-	-	10^S	60	-	-	R	1978
USSR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	1977
United States																						
- NIOSH	-	-	9.6	45	-	-	4.4	30	-	-	0.2	1.0	-	-	50	240	-	-	1	5	G	1978
- OSHA	-	-	-	45	-	270	-	-	-	2.8	-	-	-	240	-	-	-	60	-	-	R	1978
- ACGIH	5^S	22	10.0^S	44	25	135	-	-	0.1	0.5	-	-	50	240	75	360	1	6	-	-	G	1983/84
Yugoslavia	10	45	-	-	50	270	-	-	0.5	2.8	-	-	50	240	-	-	10	60	-	-	R	1971

* TWA = time-weighted average exposure limit.
**STEL = short-term exposure limit. (Generally 15 minutes, except for Great Britain which has a 10-min exposure limit.)

Note: S = skin

Some of the ILO data published in 1980 may now be out of date if some countries follow ACGIH guidelines which are updated annually.

APPENDIX VIIIe

RATIONALES USED BY ACGIH AND NIOSH FOR EXPOSURE LIMITS ESTABLISHED FOR SOME SUBSTANCES USED IN EPOXY RESIN SYSTEMS

Substance	ACGIH Rationale	NIOSH Rationale
Epichlorohydrin	TWA of 8 mg/m^3 (2 ppm) is primarily due to evidence of burning of the eyes and nasal mucosa at 82 mg/m^3 (20 ppm) (Wexler, 1971); evidence of lung, liver and kidney injury in humans at exposures in excess of 100 ppm (Union Carbide, 1971; Wexler, 1971); cancers in mice (Van Duuren, 1974); and mutagenic effects in microbial systems and the fruit fly (NIOSH, 1976).	TWA of 2 mg/m^3 (0.5 ppm) is based on "professional judgment rather than quantitative data" although the minimal concentration of 20 mg/m^3 (about 5 ppm) observed to induce effects on rats was a factor in approximating the permissible exposure in the occupational environment (NIOSH, 1976).
Diethylenetriamine (DETA)	TWA of 4 mg/m^3 (1 ppm) is recommended due to DETA's capacity to cause severe corneal injury (Sutton, 1963), pulmonary and cutaneous sensitization (Dernehl, 1951) and its potential to cause greater respiratory tract irritation and sensitization than ethylamine (ACGIH, 1980).	No NIOSH exposure criteria.
4,4'-methylene-dianiline (MDA)	TWA of 0.8 mg/m^3 (0.1 ppm) is based primarily on studies by McGill and Motto (1974) and Dow Chemical (1977). In the McGill and Motto study, mill operators exposed to MDA concentrations of 0.1 ppm were not adversely affected. The study of Dow workers covered a period of 26 years and no morbidity findings were reported for MDA exposures ranging from 0.03 to 0.4 ppm.	No NIOSH exposure criteria.
Allyl glycidyl ether (AGE)	TWA of 22 mg/m^3 (5 ppm) is believed to be sufficiently low to prevent primary irritation although may not protect against sensitization in all workers (ACGIH, 1980). TWA was assigned after reviewing several cases of dermatitis and one case of eye irritation from worker exposure and a number of animal studies involving systemic toxicity.	STEL of 45 mg/m^3 (9.6 ppm) is considered an adequate safety margin in view of evidence of eye irritation and respiratory distress in rats at 1,210 mg/m^3 (260 ppm) and mutagenic activity in bacteria (NIOSH, 1978b).

Appendix VIIIe
Rationales Used by ACGIH and NIOSH for Exposure Limits Established for Some Substances Used in Epoxy Resin Systems - 2

Substance	ACGIH Rationale	NIOSH Rationale
n-Butyl glycidyl ether (BGE)	TWA of 135 mg/m^3 (25 ppm) is recommended based on animal studies and limited human exposures described by Hine et al (1956), and animal studies using closely related isopropyl glycidyl ether. ACGIH indicates that the NIOSH recommended standard of 30 mg/m^3 (4.4 ppm) seems unjustified in view of the limited evidence of mutagenic effects in microbial and mammalian test systems (ACGIH, 1980).	STEL of 30 mg/m^3 (4.4 ppm) is the lower limit of detectability permitted by the NIOSH sampling and analytical method; this level is recommended in view of evidence of mutagenicity in microbial and mammalian test systems (NIOSH, 1978b).
Diglycidyl ether (DGE)*	In view of the seriousness of some of the effects produced by DGE (e.g., skin cancer in mice, residual effects on blood cells at 3 ppm, and acute irritation of the eyes and respiratory tract at 10 ppm), a TWA of 0.5 mg/m^3 (0.1 ppm) was recommended which is below the "no-ill-effects" level of 0.3 ppm after 60 exposures (ACGIH, 1980).	STEL of 1.0 mg/m^3 (0.2 ppm) is recommended in view of testicular changes in rats at 1.6 mg/m^3 (0.3 ppm), documentation of other systemic effects, evidence of tumorigenic activity in mice and mutations in bacteria (NIOSH, 1978b).
Isopropyl glycidyl ether (IGE)	TWA of 240 mg/m^3 (50 ppm) is believed to be low enough to prevent systemic effects but industrial experience is inadequate to indicate whether irritation of eyes or respiratory passages will occur at this level (ACGIH, 1980).	STEL of 240 mg/m^3 (50 ppm) is recommended because only slight irritation was produced in rats at exposures of 1,900 mg/m^3 (400 ppm) and no effects have been demonstrated in the occupational environment (NIOSH, 1978b).
Phenyl glycidyl ether (PGE)	TWA of 6 mg/m^3 (1 ppm) is based on studies by Terrill and Lee (1977) where rats were exposed to PGE over a period ranging from 2 to 9 weeks causing adverse effects at 29 ppm and loss of hair at 12 and 5 ppm.	STEL of 5 mg/m^3 (1 ppm) is recommended in view of irritation to animals at concentrations of 30 mg/m^3 (5 ppm) and no effects at 5 mg/m^3 (1 ppm) (NIOSH, 1978b).

*Use of DGE in Ontario is unlikely.

APPENDIX IX

EPOXY RESIN QUESTIONNAIRE

EPOXY RESIN QUESTIONNAIRE

1 - Name of establishment _____

_____

2 - Head office address _____

_____

3 - Ontario plant sites _____

_____

_____

4 - Persons interviewed

Name	Position	Telephone

5 - Amount of epoxy resins produced or used in 1982

	Produced (t)	Used (kg)
Bisphenol A/epichlorohydrin resins	_____	____
Epoxy novolac resins	_____	____
Aliphatic epoxy resins	_____	____
Cycloaliphatic epoxy resins	_____	____
Brominated epoxy resins	_____	____
High-functionality epoxy resins	_____	____
High-molecular-weight, linearized resins	_____	____
Flexibilizing epoxy resins	_____	____
Other (specify) _____	_____	____

6 - Projected increase/decrease (inc/dec) in production/usage over next 5 years.

Resin Type	Prod/Use	1983 Inc (%)	1983 Dec (%)	1984 Inc (%)	1984 Dec (%)	1985 Inc (%)	1985 Dec (%)	1986 Inc (%)	1986 Dec (%)	1987 Inc (%)	1987 Dec (%)

7 - Identify chemicals associated with production, usage and/or curing of epoxy resins by your company.

Production Chemicals	Amount Used in 1982 (kg)
e.g. epichlorohydrin	
bisphenol A	
sodium hydroxide	
diglycerol ether (reactant)	
propylene	
other _____	
Reactants	
e.g. bisphenol A	
tetrabromo bisphenol A	
o-cresol	
paraformaldehyde	
caustic soda	
oxalic acid	
p-tertiary butyl phenol	
other _____	
_____	

Amount Used in 1982 (kg)

Solvents

e.g. methyl ethyl ketone _____
methyl isobutyl ketone _____
acetone _____
toluene _____
xylene _____
other _____ _____
_____ _____

Curing Agents

Polyamines

Aliphatic, e.g. diethylene/triamine (DETA) _____
triethylenetetramine (TETA) _____
amine-ethyl piperazine _____
other _____ _____

Aromatic, e.g. m-phenylenediamine _____
4, 4' methylene-dianiline _____
4, 4' diaminodiphenyl sulfone _____
other _____ _____

Polyamides

(specify chemical _____) _____

Acid Anhydrides

e.g. Phthalic Anhydride _____
Nadic methylanhydride (NMA) _____
hexahydrophthalic anhydride (HHPA) _____

Catalytic Curing Agents

e.g. dicyandiamide _____
benzyl dimethylamine _____
boron trifluoride-monoethylamine (BF_3-MEA) _____
other _____ _____

	Amount Used in 1982 (kg)
Amino/Phenoplast Resin Curing Agents	
e.g. melamine	
phenol	
urea formaldehyde	
Other Additives (identify)	
Accelerators	
Fillers	
Reinforcements	
Glycidal Ethers	

8 - If a user of epoxy resins, what are your end products?

	Epoxy Resin Type	Amount Used in 1982
Protective coatings (specify type, e.g. automotive, appliance, electrical, metal containers, etc.		
Reinforced plastics (specify product, e.g., aircraft, tanks, pipe, etc.		
Bonding, adhesives		
Epoxy powders		
Vinyl esters		
Casting resins		
Other (specify)		

9 - Number of plant employees _____

10 - Plant employees or other personnel exposed to epoxy resin and related chemicals.

Occupational Category	No. of Workers	Duration of Exposure e.g., full shift, occasional walk-through, etc

MONITORING

11 - What processes and/or procedures in your plant are likely to result in worker exposure to epoxy resin emissions? (Include fugitive emissions and spills). What is nature of exposire, i.e. chemicals emitted? _____

12 - Does your firm monitor exposure to epoxy resins or any related chemicals? _____

13 - How are the samples collected? _____

14 - Location and nature of sampling.

Chemical Substance Monitored	Sample Site	Number of Samples and Frequency of Sampling	Duration of Sampling	Average Exposure Levels	Maximum Exposure Levels	Type of Sampling, (personal, TWA, work area, short-term)

15 - What method is used to analyze the samples?

Chemical Substance Analyzed	Analytical Technique

16 - Specify total annual costs for sampling and analysis re epoxy resins 1982. $ _____

MEDICAL MONITORING

17 - Are pre-employment medical examinations administered to employees who will be working with epoxy resins?

_____

18 - Which of the following items are included in pre-employment medical examination?

- pulmonary function tests
- work history
- medical history
- blood analysis
- urinalysis
- patch testing
- other (please describe) _____

19 - Are periodic medical examinations conducted for employees exposed to epoxy resins? _____

_____

20 - Which of the following items are included in the periodic examinations? (indicate frequency after each item)

- blood analysis _____
- urinalysis _____
- other _____

21 - What medical personnel are available in your establishment?

	Physician	Nurse	Other
Full-time	_____	_____	_____
Part-time	_____	_____	_____
Contract	_____	_____	_____
Fee-for-service	_____	_____	_____

Other _____

22 - What are the total annual costs for periodic medical examinations and tests? _____

_____

23 - Are medical records of employees exposed to epoxy resin emissions maintained? _____

_____

24 - Are medical records of former employees who worked with epoxy resins maintained? _____

_____

25 - What are the total annual costs of maintaining medical records?

_____

_____

EXPOSURE CONTROL PROCEDURES

26 - Which of the following administrative controls are used in your plant to limit worker exposure to epoxy resin emissions?

- worker rotation
- transfer of sensitized workers
- limitation of production time
- others (please describe)

_____

_____

_____

27 - What personal protective equipment is available in your plant for workers exposed to epoxy resin emissions?

Equipment	Area/Process/ Operation	No. of Workers	Conditions for Use	Mandatory or Optional
Overalls				
Gloves				
Aprons				
Safety goggles				
Face shield				
Respirators type_____				
Hygiene Facil. Sep. lunchrooms				
Showers				
Other _____				
Other Equipment Specify _____				

Is non-compliance a problem? Yes ___ No ___

Is equipment checked, maintained and replaced regularly?

Yes ___ No ___. State frequency _____

28 - What are the total annual costs to your firm for personal protective equipment and clothing re epoxy resins? (include costs for regular equipment inspection and maintenance).

_____

_____

29 - Please supply the following information on engineering controls presently in place to reduce worker exposure to epoxy resins.

Control Device	Year of Installation	Capital Cost	Annual Operating Expense	Life Expectancy

30 - Are there any substitutes for epoxy resins (or other types) that could be used in your operation? _____

_____

31 - What type of regulatory strategy would you like to see the government introduce for the control of worker exposure to epoxy resins?

A - Voluntary Exposure Limit

B - Mandatory Exposure Limit

C - A comprehensive standard with mandatory medical examination, record keeping, monitoring and exposure limit requirements

D - Other (please describe) _____

_____

32 - What would be the economic impact of these various control strategies on your company if the Ministry introduced a regulation similar to proposed Ontario guidelines? Similar to NIOSH, OSHA and/or ACGIH regulations or recommendations?

_____

_____

EMPLOYEE EDUCATION AND TRAINING

33 - Does your firm provide any special education and training for employees who may be exposed to epoxy resins? _____

_____

34 - Briefly describe the training and education program offered (include content and length of classes, films, availability of written materials, frequency of training sessions). _____

_____

_____

35 - Are warning signs posted in areas where exposure to dangerous substances associated with epoxy resins may occur? What kind of signs, bilingual or pictograms?

_____

36 - Do you provide workers with chemical safety data sheets for epoxy resins or any of the chemicals associated with these resins? _____

_____

WORKER CONCERNS

37 - Have any general concerns been raised by employees about the possible hazards of epoxy resins? Yes ___ No ___

38 - Have any specific concerns been raised about illnesses which may be associated with epoxy resins? Yes ___ No ___

If yes, describe _____

_____

_____

39 - How were the concerns raised?

- Health and Safety Committee _____
- Union representative _____
- Directly to management _____
- During Ministry inspections _____

40 - What actions have been taken as a result of concerns?

_____

_____

_____

_____

_____

LIST OF REFERENCES

LIST OF REFERENCES

Adams, R. M.
"Allergen Replacement in Industry"
CUTIS 20:511 - 516
1977

Adams, R. M.
Occupational Skin Disease
Grune and Stratton, New York
1983

Ahmad, D., W.K.C. Morgan, R. Patterson, T. Williams and C. R. Zeiss
"Pulmonary Hemorrhage and Haemolytic Anaemia Due to Trimellitic Anhydride"
The Lancet
pp 328 - 330
August 18, 1979

Allen, H. and K. Kaidbey
Persistent Photosensitivity Following Occupational Exposure to Epoxy Resin
Archives of Dermatology 115:1307 - 1310
November 1979

American Conference of Governmental Industrial Hygienists
Documentation of Threshold Limit Values
4th ed
1980

American Conference of Governmental Industrial Hygienists
Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment With Intended Changes for 1983-84
Cincinnati, Ohio

Ancona-Alayon, A., J. L. Jiminez-Castilla and E. M. Gomez-Alvarez
"Dermatitis from Epoxy Resin and Formaldehyde in Shampoo Packers"
Contact Dermatitis 2:356 - 364
1976

Andersen, M., P. Kiel, H. Larsen and J. Maxild
"Mutagenic Action of Aromatic Epoxy Resins"
Nature 276:291
November 23, 1978

Andersson, R., K. Goransson, G. Andersson, S. Marklund and P. Zingmark
"Epidemic Occupational Photodermatosis of the Face"
The Lancet
p 472
February 26, 1983

Berger, J. E., K. I. Darmer and C. F. Phillips
"Health, Safety and Environmental Factors Affecting Epoxy Resins"
High Solids Coatings 5(4):16 - 30
December 1980

Boiano, J. M.
Health Hazard Evaluation Report No. HHE-80-165-907
International Harvester Truck Engineering and Design Center, Fort Wayne, Indiana
Prepared for NIOSH
Cincinnati, Ohio
June 1981

Bokelund, F., S. Fregert and L. Trulsson
"Sensitization from Epoxy Resin Powder of High Molecular Weight"
Contact Dermatitis 6(2):144
1980

Bourne, L. G., F.J.M. Milmer and K. B. Alberman
"Health Problems of Epoxy Resins and Amine Curing Agents"
Br. J. Ind. Med. 16:81
1959
(As referenced by H. R. Hosein in "Some Experiences With Epoxy Resin Grouting Compounds", Am Ind Hyg Assoc J 41:523 - 525, 1980.)

Breitigam, W. V.
"Epoxy"
In Modern Plastics Encyclopedia
p. 32
1982 - 1983

Brubaker, R. E., H. J. Muranko, D. B. Smith, G. J. Beck and G. Scovel
"Evaluation and Control of a Respiratory Exposure to 3-(Dimethylamine) Propylamine"
J. Occup Med 21(10):688 - 690
1979

Bruins, P. E. (ed)
Epoxy Resin Technology
Interscience Publishers
1968

Calnan, C. D.
"Studies in Contact Dermatitis IV Epoxy Resins"
Transactions of the St. John's Hospital Dermatological Society
40:12 - 19
1958
(As referenced by S. Fregert and A. Thorgeirsson in "Patch Testing with Low Molecular Oligomers of Epoxy Resins in Humans", Contact Dermatitis 3:301 - 303, 1977.)

Canadian Paint and Coatings Association
"Use of Epoxy Resins in the Ontario Paint and Coatings Industry"
Prepared for Acres Consulting Services Limited on behalf of the Ontario Paint Association and the Canadian Paint and Coatings Association
January 13, 1984

Clayton, G. D. and F. G. Clayton (ed)
Patty's Industrial Hygiene and Toxicology
Toronto
Wiley Interscience Publication
Vol 2
1981

Cohen, S. R. and A. A. Maier
"Occupational Health Case Report No. 4 - Epoxy-Type Paint"
J. Occup Med 16(3):201 - 203
March 1974

Colombi, A., M. Maroni, G. Marasi and V. Foa
"Determination of Total Aromatic Amines in Urine, Using a Column Extractive Method"
Med Lav (Italy) 72(6):514 - 515
November - December 1981

Conde-Salazar, L., L. Romero, D. Guimaraens and A. Harto
"Contact Dermatitis in an Oil Painter"
Contact Dermatitis 8(3):209 - 210
May 1982

Consumer and Corporate Affairs Canada, Product Safety Branch, Ottawa, Ontario
"Analysis of Epoxy Glues for Epichlorohydrin"
1981

Corpus Information Services Limited
Corpus Product Profile - Epoxy Resins (Epoxies)
April 15, 1981

Cummins, J. E.
Mutagenicity of Epoxy Formulations I, Epoxy Resin Component
Department of Plant Sciences, University of Western Ontario
Unpublished

Cummins, J. E. and P. A. Marck
"Epoxy Novolac Resins - A New Family of Industrial Mutagens"
Department of Plant Sciences, University of Western Ontario
Unpublished

Cwitco, G.
Personal communication with National Representative of Communication Workers of Canada
February 14, 1984

Dahlquist, I., S. Fregert, K. Persson and L. Trulsson
"Epoxy Resin in a One-Pack Glue"
Contact Dermatitis 5:189 - 190
1979a

Dahlquist, I., S. Fregert and L. Trulsson
"Allergic Contact Dermatitis from Epoxy Resin Finished Glass Fiber"
Contact Dermatitis 5:190
1979b

Dahlquist, I. and S. Fregert
"Contact Allergy to Cardura E, an Epoxy Reactive Diluent of the Ester Type"
Contact Dermatitis 5(2):121 - 122
1979c

Dernehl, C. U.
"Clinical Experiences with Exposures to Ethylene Amines"
Ind Med Surg 20:541
1951
(As referenced by H. R. Hosein in "Some Experiences with Epoxy Resin Grouting Compounds", Amer Ind Hyg J 41:523 - 525, 1980.)

Dernehl, C. U. "Hazards to Health Associated with the Use of Epoxy Resins"
J. Occup Med 5:17
1963
(As referenced by Fawcett et al in "Asthma Due to Inhaled Chemical Agents - Epoxy Resin Systems Containing Phthalic Acid Anhydride, Trimellitic Acid Anhydride and Triethylene Tetramine", Clinical Allergy 7:1 - 14, 1977.)

DiStasio, J. I. (ed)
"Epoxy Resin Technology Developments Since 1979"
Noyes Data Corporation, Park Ridge, New Jersey
1982

Dow Chemical Canada Inc
Personal Communication with R. B. McCall, Product Manager, Epoxy Resins
March 2, 1984a

Dow Chemical Canada Inc
Personal Communication with George Woods
June 14, 1984b

Dow Chemical Canada Inc
Personal Communication with Don Poland
September 1984c

Dow Chemical Co
"Dow Epoxy Novolac Resins"
Midland, Michigan
1978

Dow Chemical Co
"Storage and Handling - Dow Epoxy Curing Agents"
1981

Dowd, R. T.
"General Chemistry of Bisphenol A-Based Epoxy Resins"
In P. F. Bruins (ed) Epoxy Resin Technology, Chapter 1
1968

Dunn, G. W.
Private communication from the Ontario Ministry of Labour
(As referenced by ACGIH in "Documentation of Threshold Limit Values", 4th ed, p 278, 1980.)

Dunn, G. W. and S. S. Guirguis
pp'-Methylene Dianiline (MDA) as an Occupational Health Problem. A Suggested Time-Weighted Average Exposure Level and Medical Program
Ahr.hig.rada toksikol 30:639 - 645
1979

Ehrenberg, Professor
Comment made at Conference on Health Hazards from Epoxy
H. Ehrner-Samuel and O. Sjoholm (ed)
Stockholm Sweden
April 24, 1974
pp 60 - 61
Proceedings printed in 1976

Ehrner-Samuel, H. and O. Sjoholm (ed)
Conference on Health Hazards from Epoxy.
Stockholm, Sweden, April 24, 1974
Proceedings printed in 1976

Enterline, P.
Letter from P. Enterline, Ph.D., Department of Biostatistics, University of Pittsburgh to R. E. Joyner, M.D., Corporate Medical Director, Shell Oil Co.
July 31, 1978 (as quoted by NIOSH, 1978a)

Enviro Control Inc
Engineering Control Technology Assessment for the Plastics and Resins Industry
Prepared for NIOSH, Div of Physical Sciences and Engineering
March 1978

Fawcett, I. W., A. J. Newman Taylor and J. Pepys
"Asthma Due to Inhaled Chemical Agents - Epoxy Resin Systems Containing Phthalic Acid Anhydride, Trimellitic Acid Anhydride and Triethylene Tetramine"
Clinical Allergy 7:1 - 14
1977

Fernandez, J. A.
Personal Communication with Vice-President (Technical), Le Page's Limited
September 13, 1984

Firmingham, D. J.
"Contact Dermatitis from Synthetic Resins"
J. Arkansas Medical Society 65(10):370 - 372
1969

Fisch, W., W. Hofmann and R. Schmid
"Chemistry of Epoxide Resins XVII. Influence of Structure and Curing Conditions on the Density, Degree of Cure and Glass Transition"
J. Applied Polymer Science 13:295 - 308
1969
(As referenced by Fregert et al in "Allergic Contact Dermatitis from Unhardened Epoxy Resin in a Finished Product", Contact Dermatitis 5(4):277 - 278, 1979.)

Fregert, S.
"Epoxy Dermatitis from the Non-Working Environment"
Br. J. Dermatol 105 (Supplement 21):63 - 64
1981
(As referenced by R. M. Adams in "Occupational Skin Disease", New York, Grune and Stratton, p 246, 1983.)

Fregert, S., K. Persson and L. Trulsson
"Allergic Contact Dermatitis from Unhardened Epoxy Resin in a Finished Product"
Contact Dermatitis 5(4):277 - 278
1979

Fregert, S. and A. Thorgeirsson
"Patch Testing with Low Molecular Oligomers of Epoxy Resins in Humans"
Contact Dermatitis 3:301 - 303
1977

Frost, A. F. and M. S. Legator
"Unscheduled DNA Synthesis Induced in Human Lymphocytes by Butyl Glycidyl Ethers"
Mutation Research 102:193-200
1982

Gaul, L. E.
"Prevalence of Epoxy Resin Dermatitis"
Arch Derm 96:227 - 230
1967

Geissert, J. O.
Technical Assistance Report No. TA-76-66, Mr. Gary Armstrong, Cincinnati, Ohio
Prepared for NIOSH
Cincinnati, Ohio
March 1977

Gilles, D.
Health Hazard Evaluation Determination Report
No. 75-147-318
Westinghouse Electric Corporation, East Pittsburgh,
Pennsylvania
Prepared for NIOSH
Cincinnati, Ohio
August 1976

Gleason, M. N., R. E. Gosselin, H. C. Hodge and R. P. Smith
Clinical Toxicology of Commercial Products
3rd ed
Baltimore
Williams and Wilkins
1969

Goransson, K., R. Andersson, G. Andersson, S. Marklund,
K. Andersson, P. Ostbye and P. Zingmark
"An Outbreak of Occupational Photodermatosis of the Face in a
Factory in Northern Sweden", Part I - Medical Investigation
Presented at the 3rd International Conference on Indoor Air
Quality in Stockholm, Sweden
August 20-24
1984

Göransson, K., R. Andersson, G. Andersson, S. Marklund,
K. Andersson, P. Ostbye and P. Zingmark
"An Outbreak of Occupational Photodermatosis of the Face in a
Factory in Northern Sweden", Part II - Chemical and
Technical Investigation
Presented at the 3rd International Conference on Indoor Air
Quality in Stockholm, Sweden
August 20-24
1984

Gunter, B. J. and J. B. Lucas
Health Hazard Evaluation/Toxicity Determination, Head Ski
Company, Boulder, Colorado
Prepared for NIOSH
Cincinnati, Ohio
March 1974

Hambly, E. M. and D. S. Wilkinson
"Unusual Presentation of Epoxy Resin Sensitivity"
Contact Dermatitis 4:114 - 120
1978

Handlovits, C. E.
"Epoxy"
In Modern Plastics Encyclopedia 1983 - 1984
Vol 60, No. 10A
New York
McGraw Hill
October 1983

Henderson, J. F., M. G. Holliday and A. Holmes
"Occupational Health Implications of the Use of Formaldehyde in Ontario"
Prepared for Ontario Ministry of Labour
1980

Herbert, F. A. and R. Orford
"Pulmonary Hemorrhage and Edema Due to Inhalation of Resins Containing Trimellitic Anyhdride"
Chest 76(5):546 - 551
November 1979

Hine, C. H., J. K. Kodama, J. S. Wellington, M. K. Dunlap and H. H. Anderson
Arch Ind Health 14:250
1956
(As referenced by ACGIH in "Documentation of Threshold Limit Values," 4th ed, 1980.)

Hine, C. H., J. K. Kodama, H. H. Anderson, D. W. Simonson and J. S. Wellington
"The Toxicology of Epoxy Resins"
AMA Arch Ind Health 17:129 - 144
1958a
(As referenced by Berger et al in "Health, Safety and Environmental Factors Affecting Epoxy Resins", High Solids Coatings 5(4):16 - 30, December 1980.)

Hine, C. H., R. J. Guzman, M. M. Coursey, J. S. Wellington and H. H. Anderson
"An Investigation of the Oncogenic Activity of Two Representative Epoxy Resins"
Cancer Research 18:20 - 26
1958b
(As referenced by Berger et al in "Health, Safety and Environmental Factors Affecting Epoxy Resins", High Solids Coatings 5(4):16 - 30, December 1980.)

Hine, Charles, V. K. Rowe, E. R. White, K. I. Darmer, Jr., and G. T. Youngblood
"Epoxy Compounds"
In G. D. Clayton and F. E. Clayton (ed) Patty's Industrial Hygiene and Toxicology
Vol 2, Chapter 32
pp 2141 - 2257
Toronto
A. Wiley Interscience Publication
1981

Holland, J. M., L. C. Gipson, M. J. Whitaker, B. M. Eisenhower and T. J. Stephens
"Chronic Dermal Toxicity of Epoxy Resins. I - Skin Carcinogenic Potency and General Toxicity"
Oak Ridge National Laboratory, Oak Ridge, Tennessee
1981

Holland, J. M.
Oak Ridge National Laboratory, Oak Ridge, Tennessee
"Comments at Workshop on the Toxicology of Epoxy Resins"
October 18, 1980
(As recorded in internal memorandum of Society of the Plastics Industry of Canada, dated October 29, 1980.)

Holland, J. M., D. G. Gosslee and N. J. Williams
"Epidermal Carcinogenicity of Bis(2,3-epoxycyclopentyl) ether, 2,2-Bis(p-gylcidyloxyphenyl)propane, and m-phenylenediamine in Male and Female C3H and C57BL/6 Mice"
Cancer Research 39:1718 - 1725
May 1979

Hosein, H. R.
"Some Experiences with Epoxy Resin Grouting Compounds"
American Industrial Hygiene Assoc Journal
pp 523 - 525
July 1980

Ingberman, A. K., R. K. Walton, C. F. Pitt and M. N. Paul
Ind Eng Chem 49:1105
1957
(As referenced by C. A. May and Y. Tanaka in "Epoxy Resins Chemistry and Technology", p 726, 1973.)

International Agency for Research on Cancer
IARC Monographs on the Evaluation of Carcinogenic Risks of Chemicals to Man
Vol II - Epichlorohydrin
Lyon, France
pp 131 - 139
1976

International Labour Office
"Occupational Exposure Limits for Airborne Toxic Substances
2nd rev ed
Geneva
1980

Jarvisalo, J., P. Pfaffli and H. Vainio (eds)
Industrial Hazards of Plastics and Synthetic Elastomers
Proc. of Int. Symp. on Occup. Hazards Related to Plastics and Synthetic Elastomers, Espoo, Finland, November 22 to 27, 1982
pp 385 - 393
Alan R. Liss Inc., New York
1984

Kent, J. A. (ed)
Riegel's Handbook of Industrial Chemistry
Eighth Edition, Van Nostrand Reinhold Co.
New York
p 348
1983

Kidd, W. L. and L. M. Screenby
"Oncogenic Properties of High Polymers in Mice"
J. Natl Cancer Inst 25(4):749 - 751
1960
(As referenced by Berger et al in "Health, Safety and Environmental Factors Affecting Epoxy Resins", High Solids Coatings 5(4):16 - 30, December 1980.)

Kirk-Othmer Encyclopedia of Chemical Technology
3rd ed
John Wiley and Sons Inc
Vol 9
1980

Krajewska, D. and E. Rudzki
"Sensitivity to Epoxy Resins and Triethylenetetramine"
Contact Dermatitis 2(3):135 - 138
June 1976

Kucerová, M., V. S. Zhurkov, Z. Polívková, and J. E. Ivanova
Mutagenic Effect of Epichlorohydrin, II Analysis of Chromosomal Aberrations in Lymphocytes of Persons Occupationally Exposed to Epichlorohydrin
Mutation Research 48:355 - 360
1977 (as quoted by NIOSH, 1978a)

Lachapelle, J. M., D. Tennstedt and M. Dumont-Fruytier
"Occupational Allergic Contact Dermatitis to Isophorone Diamine (IPD) Used as an Epoxy Hardener"
Contact Dermatitis 4:109 - 112
1978

Lawrence, W., H. M. Malik and J. Autian
Development of a Toxicity Evaluation Program for Dental Materials and Products, II, Screening System for Toxicity
J Biomed Mater Res 8(1):11 - 34
January 1974

Lea, A. W., W. D. Block and H. H. Cronish
"The Irritating and Sensitizing Capacity of Epoxy Resins"
Arch Dermatol 78:304 - 308
1958
(As referenced by O.G.T. Mathias in "Penetrating Effects of Epoxy Resin Systems", Occupational Health and Safety, pp 43 - 44, May 1981.)

Lee, H. L. and K. O. Neville
"Epoxy Resins - Their Applications and Technology"
New York
McGraw-Hill
1957
(As referenced by Fregert et al in "Allergic Contact Dermatitis from Unhardened Epoxy Resin in a Finished Product", Contact Dermatitis 5(4):277 - 278, 1979.)

Lee, H. L. and K. O. Neville
Handbook of Epoxy Resins
Toronto
McGraw-Hill Book Co
1967

Lemon, R. C.
"Epoxy Resins in Surface Coatings"
Ann Occup Hyg (England) 15(1):131 - 137
April 1972

Malten, K. E. and R. L. Zielhuis
Industrial Toxicology and Dermatology in the Production and Processing of Plastics
New York
Elsevier Publishing Co
1964
(As referenced by S. Fregert and A. Thorgeirsson in "Patch Testing with Low Molecular Oligomers of Epoxy Resins in Humans", Contact Dermatitis 3:301 - 303, 1977.)

Mathias, C.G.T.
Penetrating Effects of Epoxy Resin Systems
Occupational Health and Safety
pp 42 - 44
May 1981

May, C. and Y. Tanaka
"Epoxy Resins Chemistry and Technology"
New York
Marcel Dekker
1973
(As referenced by Fregert et al in "Allergic Contact Dermatitis from Unhardened Epoxy Resin in a Finished Product", Contact Dermatitis 5(4):277 - 278, 1979.)

McGill, D. B. and J. D. Motto
"An Industrial Outbreak of Toxic Hepatitis Due to Methylenedianiline"
The New England Journal of Medicine
pp 278 - 281
August 8, 1974

Meadway, J.
"Asthma and Atopy in Workers with an Epoxy Adhesive"
British J. Diseases of the Chest 74:149 - 154
1980

Meath, A. R.
"Chemistry, Properties and Applications of Epoxy Novolac, Flexible Epoxy and Flame Retardant Epoxy Resins"
In P. F. Bruins (ed) Epoxy Resin Technology, Chapter 3
1968

Milby, T. H., M. D. Whorton, H. A. Stubbs, C. E. Ross, R. E. Joyner and L. I. Lipshultz
"Testicular Function Among Epichlorohydrin Workers"
B J Ind Med (England) 38(4):372 - 377
November 1981

Milby, T. H. and D. Whorton
"Epidemiological Assessment of Occupationally Related, Chemically Induced Sperm Count Supression"
Journal of Occupational Medicine 22(2):77 - 82
February 1980

Mitelman, F., S. Fregert, K. Hedner and
K. Hillbertz-Nilsson
"Occupational Exposure to Epoxy Resins Has No
Cytogenetic Effect"
Mutation Research 77:345 - 348
1980

Morrison, R. T. and R. N. Boyd
"Organic Chemistry"
2nd ed
Boston
Allyn and Bacon Inc
1966

Murray, M. P. and J. E. Cummins
"Mutagenic Activity of Epoxy Embedding Reagents Employed
in Electron Microscopy"
Environmental Mutagenesis 1:307 - 313
1979

Nakano, Y., K. Nakano, and I. Hara
"Induction of Leucocyte Migration Inhibitory Factor (LIF) by
Stimulation With Free Haptem and Water-Insoluble Epoxy
Resin"
Clinical and Experimental Immunology 45:419 - 426
1981

Napier, D. H.
Personal communication regarding chemical formulae of some
compounds associated with epoxy resins
Department of Chemical Engineering and Applied Chemistry,
University of Toronto
February 17, 1984

New York University Institute of Environmental Medicine:
Personal Communication to the NIOSH Technical Evaluation
and Review Branch, Office of Extramural Coordination and
Special Projects (1978)
(As quoted by NIOSH, 1978a)

Nielsen, P. O.
"Properties of Epoxy Resins, Hardeners, and Modifiers"
Adhesives Age
pp 42 - 46
April 1982

NIOSH
Criteria For a Recommended Standard - Occupational Exposure
to Epichlorohydrin
U.S. Department of Health, Education and Welfare
1976

NIOSH
Manual of Analytical Methods
Vol 2 - Epichlorohydrin
pp S118-1 - S118-8
1977a

NIOSH
Manual of Analytical Methods
Vol 1 - Aliphatic Amines in Air
pp 221-1 - 221-9
1977b

NIOSH
Current Intelligence Bulletin 30 - Epichlorohydrin
U.S. Department of Health, Education and Welfare
October 12, 1978a

NIOSH
Criteria for a Recommended Standard - Occupational Exposure to Glycidyl Ethers
U.S. Department of Health, Education and Welfare
1978b

NIOSH
Manual of Analytical Methods
Vol 1 - 7
1977 - 1980

NIOSH
Current Intelligence Bulletin 29 - Glycidyl Ethers
U.S. Department of Health, Education and Welfare
October 12, 1978c

NIOSH
Health Hazard Evaluation Determination Report No. 79-7-639, Greenheck Fan Corp
Schofield, Wisconsin
December 1979

NIOSH
Manual of Analytical Methods
Vol 6 - Bisphenol A and Diglycidyl Ether of Bisphenol A
pp 331-1 - 333-6
1980

NIOSH
"Recommendations for Occupational Health Standards"
Morbidity and Mortality Weekly Report
Vol 32(15)
October 7, 1983

Oak Ridge National Laboratory
Unpublished data
No date
(As referenced by Clayton and Clayton (ed) in "Patty's Industrial Hygiene and Toxicology", p 2241, 1981.)

Oomens, A. C. and F. G. Schuurhuis
"A Method for the Collection and Determination of Phenol and Bisphenol A in Air"
Int Arch Occup Environ Health 52(1):43 - 48
1983

Pegum, J. S.
"Penetration of Protective Gloves by Epoxy Resin"
Contact Dermatitis 5:281 - 283
1979

Perez, R. J.
"Commercial Epoxy Resin Curing Agents"
In P. F. Bruins (ed) Epoxy Resin Technology
Interscience Publishers
1968

Perry, R. H. and C. H. Chilton
Chemical Engineers' Handbook
5th ed
1973

Purdew, J. P.
"Health and Safety in the Plastics and Rubber Industries"
Proc Plastics and Rubber Inst Conf
University of Warwick
1980

Rice, D. L., D. E. Jenkins, J. M. Gray and S. D. Greenberg
"Chemical Pneumonitis Secondary to Inhalation of Epoxy Pipe Coating"
Arch Environ Health 5:173 - 177
July/August 1977

Richardson, F. B.
"Water Dispersible Epoxy Resin Curing Agents - Past, Present and Future"
Polymers Paint Colour Journal
pp 714 - 715
October 27, 1982

Rivera, M., M. B. Nicotra, G. E. Byron, R. Patterson, D. H. Yawn, M. Franco, C. R. Zeiss and S. D. Greenberg
"Trimellitic Anhydride Toxicity - A Cause of Acute Multisystem Failure"
Archives of Internal Medicine 141:1071 - 1074
July 1981

Roper, C. P.
"Health Hazard Evaluation Determination Report No. 7751-502, Martin Marietta Aerospace, Orlando, Florida"
Prepared for NIOSH
Cincinnati, Ohio
July 1978

Rudzki, E.
"Dermatitis from Epoxy Resin, Triethylenetetramine and Ethylenediamine"
Contact Dermatitis 4:53 - 64
1978

Rudzki, E.
"Some Peculiarities of Contact Dermatitis in Poland"
Dermatosen 29(4):98 - 101
1981

Rudzki, E., P. Rebandel, Z. Grzywa and B. Jakiminska
"Dermatitis From Phenyl Glycidyl Ether"
Contact Dermatitis 9(1):90 - 91
January 1983

Rycroft, R.J.G.
"Allergic Contact Sensitization to Epoxide 7 in Grinding Oil"
Contact Dermatitis 6:316 - 320
1980a

Rycroft, R.J.G.
"A Typical Psoriasis Following Epoxy Resin Sensitization"
J Soc Occup Med 30:132 - 134
1980b

Sargent, E. V., C. A. Mitchell and R. E. Brubaker
"Respiratory Effects of Occupational Exposure to an Epoxy Resin System"
Archives of Environmental Health
September/October 1976

Sax, N. I.
Dangerous Properties of Industrial Materials
5th ed
New York
Van Nostrand Reinhold Co.
1979

Schlueter, D. P., E. F. Banaszak, J. N. Fink and J. Barboriak
"Occupational Asthma Due to Tetrachlorophthalic Anhydride"
J Occup Med 20(3):183 - 188
March 1978

Shell International Chemical Co. Ltd. and Ciba-Geigy Ltd
"Skin Cancer Studies on Bisphenol A Based Epoxy Resins"
Overview of Two Recently Completed Studies
Unpublished

Silverstein, L. G.
"Safe Handling of Epoxy Resin Systems"
Chapter 6 in P. F. Bruins (ed) "Epoxy Resin Technology", Interscience Publishers, Toronto, 1968.)

Stecher, P. G. (ed)
"The Merck Index - An Encyclopedia of Chemicals and Drugs"
8th ed
Rahway, New Jersey
Merck & Co. Inc.
1968

Steinhoff, D. and E. Grundmann
"Zur cancerogenen wirkung von 4,4'-diaminodiphenylemthan und 2,4'-dimirodiphenylmethan"
Naturwissenschaften 57:247
1970
(As referenced by Wellington Environmental Consultants in "An Assessment of the Hazards of Aromatic Amines and Azo Compounds in Ontario". Prepared for Ministry of Labour, April 1983.)

Stevens, J. J., Jr.
"Chemistry Properties and Applications of Cycloaliphatic Epoxy Resins"
In P. F. Bruins (ed) Epoxy Resin Technology Interscience Publications, 1968

Suhonen, R.
"Epoxy-Dermatitis in a Ski-Stick Factory"
Contact Dermatitis 9:131 - 133
1983

Suskov, I. I. and L. A. Sazonova
"Cytogenetic Effects of Epoxy, Phenolformaldehyde and Polyvinylchloride Resins in Man"
Mutation Research 104:137 - 140
1982

Sutton, W. L.
Industrial Hygiene and Toxicology
2nd ed
New York
Interscience
Vol 2
p 2061
1963
(As referenced by ACGIH in "Documentation of Threshold Limit Values", 4th ed, p 141, 1980.)

Swank, M. G.
Private communication from Dow Chemical Co, Midland, Michigan, 1977
(As referenced by ACGIH in "Documentation of Threshold Limit Values", 4th ed, 1980.)

Terrill, J. B. and K. P. Lee
Tox Appl Pharm 42:263
1977
(As referenced by ACGIH in "Documentation of Threshold Limit Values", 4th ed, 1980.)

The Society of the Plastics Industry, Inc.
Letter to Mr. W. G. Ewald, U.S. Environmental Protection Agency, from L. R. Freeman, Jr., regarding recent health assessment of epichlorohydrin
January 6, 1984

Thorgeirsson, A., S. Fregert and B. Magnusson
"Allergenicity of Epoxy-Reactive Diluents in the Guinea Pig"
Berufsdermatosen 23:178 - 183
1975
(As referenced by S. Fregert and A. Thorgeirsson in "Patch Testing With Low Molecular Oligomers of Epoxy Resins in Humans", Contact Dermatitis 3:301 - 303, 1977.)

Thorgeirsson, A., S. Fregert and O. Ramnas
"Sensitization Capacity of Epoxy Resin Oligomers in the Guinea Pig"
Acta Dermatovener (Stockholm) 58:17 - 21
1978

Thorgeirsson, A. and S. Fregert
"Allergenicity of Epoxy Resins in the Guinea Pig"
Acta Dermato-Venerologica 57:253 - 256
1977

Union Carbide Co.
Toxicology Studies - Epichlorohydrin
1971
(As referenced by ACGIH in "Documentation of Threshold Limit Values", 4th ed, 1980.)

Vail, N. W.
"Recent Advances in Water-Based Epoxy Resin Systems"
Australian OCCA Proceedings and News
pp 5 - 11
October 1981

Van Duuren, B. L. et al.
J Natl Cancer Inst 53:695
1974
(As referenced by ACGIH in "Documentation of Threshold Limit Values", 4th ed, p 168, 1980.)

Velten, G. G.
"Epoxy"
1974 - 1975 Modern Plastics Encyclopedia
pp 30, 32
1975

Van Putten, P. G., P. J. Coenraads and J. P. Nater
"Hand Dermatoses and Contact Allergic Reactions in Construction Workers Exposed to Epoxy Resins"
Contact Dermatitis 10:146-150
1984

Ward, M. J. and D. Davies
"Asthma Due to Grinding Epoxy Resin Cured With Phthalic Anhydride"
Clinical Allergy 12:165 - 168
1982

Weil, C. S., N. Condra, C. C. Haun and J. A. Striegel
"Experimental Carcinogenicity and Acute Toxicity of Representative Epoxides"
Am Ind Hyg Assoc J 24:305
1963
(As referenced by Berger et al in "Health, Safety and Environmental Factors Affecting Epoxy Resins", High Solids Coatings 5(4):16 - 30, December 1980.)

Weil, C. S.
Unpublished data from Carnegie-Mellon Institute of Research
December 8, 1978
(As referenced by Berger et al in "Health, Safety and Environmental Factors Affecting Epoxy Resins", High Solids Coatings 5(4):16 - 30, December 1980.)

Weil, C. S.
Unpublished data from Carnegie-Mellon Institute of Research
No date
(As referenced by Clayton and Clayton (ed) in "Patty's Industrial Hygiene and Toxicology", p 2241, 1981.)

Wellington Environmental Consultants Incorporated
An Assessment of the Hazards of Aromatic Amines and Azo Compounds in Ontario
Prepared for Ontario Ministry of Labour
April 1983

Wexler, B.
Mater Plast 8:322
1971
(As referenced by ACGIH in "Documentation of Threshold Limit Values", 4th ed, p 168, 1980.)

Whorton, E. B., T. G. Pullin, A. F. Frost, A. Onofre, M. S. Legator and D. S. Folse
"Dominant Lethal Effects of n-Butyl Glycidyl Ether in Mice"
Mutation Research 124:225-233
1983

Williams, S. V., J. A. Bryan, J. R. Burke, and F. S. Wolf
Toxic Hepatitis and Methylene Dianiline
N. Eng. J. Med. 291:1256
1974
(As referenced by Dunn and Guirguis, Arh.hig.radatoksikol., 30, p 639, 1979)

Zschunke, E.
Uber die Epoxydharz-Dermatitis
Das Deutsche Gesundbeitswesen Zeitschrift fur Medizin 14:1810 - 1813
1959
(As referenced by S. Fregert and A. Thorgeirsson in "Patch Testing with Low Molecular Oligomers of Epoxy Resins in Humans", Contact Dermatitis 3:301 - 303, 1977.)